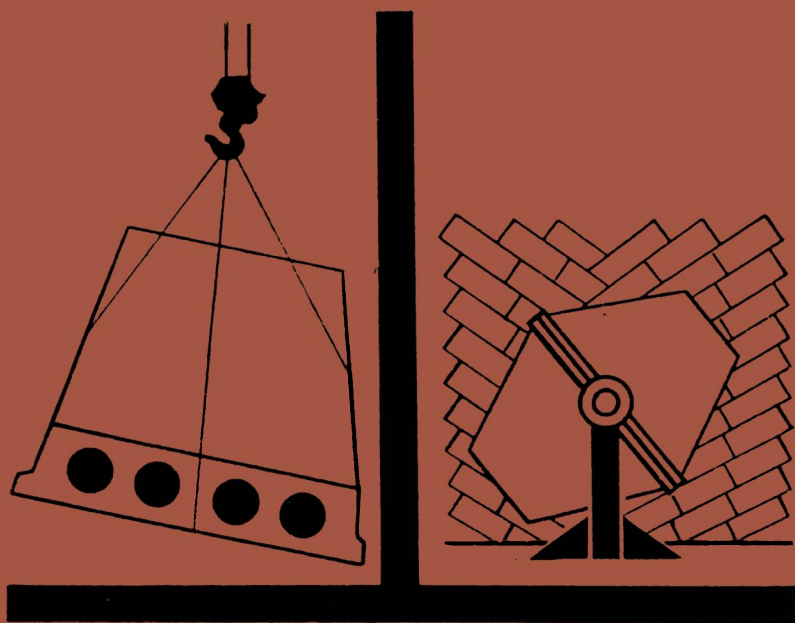


MASON'S GUIDE // MATERIALS

L. POPOV



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Л. Н. Попов

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Preface

Modern construction materials are numerous and varied.

The knowledge of the properties by workers involved in the building trade is essential for correct and rational work.

The *Mason's Guide in Materials* is intended as a text-book for students of vocational schools of masonry.

The text-book covers basic physico-mechanical properties of construction materials and units used in masonry. It describes natural and artificial stone units, mineral binding substances, mortars and concretes, also structural members made of concrete and reinforced concrete, insulation and other materials.

Chapter I

Properties of Construction Materials

Various construction materials are used in modern civil engineering. The knowledge of their properties is essential for correct choice of the materials available. The properties of the construction materials can be grouped, for the convenience of learning, into the physical, mechanical and chemical ones.

Physical properties of materials (density, bulk density, porosity, water-absorbing capacity, moisture content, water permeability, frost resistance, heat capacity, thermal conductivity, sound absorption, and fire-resistance and refractoriness) characterize their structure and behaviour in respond to the action of the environment.

Density is numerically expressed as the mass of a unit volume in the absolutely dense state, i.e., without pores and voids. The density of a material, ρ , is determined by the formula $\rho = m/V$, where m is the mass of the material, kg; V is the absolute volume of the material (without pores and voids), m^3 .

The density of majority of construction materials is more than unity. Normally it is determined by laboratory measurements and the obtained value is used to find the porosity of a construction material.

Bulk density is defined as the ratio of the mass of a material to its volume in natural state, i.e., with pores and voids. It is calculated from the following formula:

$$\rho_m = m/V_1$$

where m is the material mass, kg; V_1 is the volume of the material in natural state, m^3 .

Most of the construction materials are porous, therefore their bulk density is, as a rule, less than density. The bulk density of liquids and materials obtained from a melted mass (glass, metal) is practically equal to their density. Table 1 gives density and bulk density of some construction materials under dry-air conditions.

Bulk density is essential for the determining of porosity, thermal conductivity and heating capacity of materials, the strength of structures, and the cost of transportation. The State Standards set the limit values of moisture content of construction materials at which the bulk density should be determined.

Porosity of a material, P , is characterized by the amount of pores the material has and is found from the formula

$$P = (1 - \rho_m/\rho)100$$

where ρ_m is the bulk density of the material, kg/m³; ρ is the density, kg/m³.

This formula is also applied to determine the intergranular voids of bulk materials, but in this case the bulk-density weight of loose material and the bulk-unit weight, instead of density, are taken.

Table 1

Density and Bulk Density of Some Construction Materials

| Material | Density, kg/m ³ | Bulk density, kg/m ³ |
|------------------|----------------------------|---------------------------------|
| Granite | 2 600-2 800 | 2 600-2 700 |
| Dense limestone | 2 400-2 600 | 2 100-2 400 |
| Clay brick | 2 500-2 600 | 1 600-1 900 |
| Cement | 3 000-3 100 | 800-1 300 |
| Gravel | 2 600-2 800 | 1 400-1 600 |
| Heavy concrete | 2 600-2 900 | 1 800-2 500 |
| Mortar | 2 500-2 900 | 1 800-2 200 |
| Structural steel | 7 850 | 7 850 |
| Rigid foam | 900-1 400 | 10-20 |

Construction materials may contain both pores and voids. The pores are minute interstices in solid rock filled with water or air, whereas the voids are air-filled openings formed among the fragments of bulk materials.

The degree of porosity of a construction material is stated as a percentage; for example, glass and metal have a zero porosity, for brick it ranges from 25 to 35, heavy-weight concrete—5-10, and for cellular plastic from 90 to 95.

Porosity has a powerful influence on the physical characteristics of materials, especially water-absorbing capacity,

water permeability, frost resistance, strength and thermal conductivity, etc.

Water absorption is the capacity of a material to take up water and hold it in its pores. Water absorption may be determined as a percentage of mass or volume.

In terms of mass, it is expressed as the ratio of the mass of water absorbed at saturation of the sample to the mass of dry sample

$$A_{mass} = \frac{m_1 - m}{m} 100$$

where m is the mass of a dry sample; m_1 is the mass of the saturated sample, kg.

In terms of volume, it is defined as a ratio of the water absorbed at saturation of the sample to the volume of the sample

$$A_{vol} = \frac{m_1 - m}{V} 100$$

Relating the two values (through mass and volume), we shall obtain the bulk density of the dry material

$$\frac{A_{vol}}{A_{mass}} = \frac{m_1 - m}{V} : \frac{m_1 - m}{m} = \frac{m}{V} = \rho_m$$

Given the value of water absorption by mass and the bulk density, we may derive the formula for water absorption by volume $A_{vol} = A_{mass} \rho_m$. The absorptivity of construction materials varies within wide limits. For instance, water absorption of common clay brick is 8-20, heavy concrete—2-3, granite—0.5-0.8%.

Saturation of materials with water leads to undesirable effects: an increase in bulk density and thermal conductivity, and a reduced strength.

The water-resisting property of a material is judged by the degree of strength lost on its saturation and is expressed as a ratio of the wet compressive strength to the dry compressive strength of the sample, which will be further referred to as a wet-strength factor. This factor varies from zero (unburned clay materials) to unity (glass, steel, bitumen). Materials with the wet-strength factor of not less than 0.8 are considered as stable in water and are allowed to be used in structures raised in water and sites of increased humidity.

Water content is generally expressed as a ratio of water weight to dry material (sample) weight. It is given as a percentage using the following formula:

$$W(\text{water content}) = \frac{m_2 - m}{m} 100$$

where m_2 is the weight of the moist sample, kg; m is the weight of the dry sample, kg.

Water permeability of a material is its capacity to pass through water under pressure and is expressed by the amount of water passed for an hour through 1 sq cm of a sample under constant pressure. To the impervious materials are referred such tough materials as steel, glass, bitumen, and the materials with unpassable pores, for example, concrete of special composition.

Frost resistance is the property of a water-saturated material to sustain repeated cycles of freezing and thawing without noticeable destruction or intolerable reduction in strength.

Freezing of water filling the pores of material is followed by the increase in its volume by approximately 9% and the rise in pressure on the walls of pores, which may result in destruction of the material. However, in many porous materials water does not fill more than 90% of pore space, thus leaving a margin for expansion of ice crystals. Such materials can only be destructed by multiple cycles of freezing and thawing.

Taking into account the heterogeneity of the material structure and distribution of water in it, porous materials, in which not more than 80% of pores are filled with water, i.e. the absorption of water by volume is within the same percentage, are found to have satisfactory frost resistance.

Non-porous or slightly porous materials whose water absorption is within 0.5% are highly frost-resistant. This property is especially important for materials used for building walls, always under atmospheric action, and for those used for foundations and roof coverings.

Testing of construction materials for frost resistance is carried out in refrigerating chambers, where saturated samples are frozen at a temperature of $\text{minus } 20 \pm 5^\circ\text{C}$, then thawed in water at a temperature of $20 \pm 5^\circ\text{C}$. A material is said to be frost-resistant if the loss of sample mass, as a result of crumbling and separation of material, is within 5% and that of strength within 25%.

When the tested samples, after the specified number of freezing and thawing cycles, show no signs of destruction, the frost resistance of materials is determined by deriving a coefficient of frost resistance, K_f . It is expressed as a ratio of compressive strength of the material after frost-resistance test, R_f , to the compressive strength of water saturated material, R_s . For frost-resistant materials, K_f should be not less than 0.75.

In the USSR, all materials are divided, according to the sustained number of freezing and thawing cycles, into frost resistance grades: Fr10*, 15, 25, 35, 50, 100, 150, 200, 300, 400 and 500.

Thermal conductivity is the rate at which heat is conducted through a material when there is a temperature difference between the faces of the material. The thermal conductivity of a material is usually referred to as its λ -factor. The λ -factor depends on the nature of material, its structure, porosity and moisture content. Materials of crystalline structure have a higher conductivity than those of amorphous structure. If a material has a laminated structure (laminated plastics) or fibred structure (wood), the λ -factor will depend on the direction of heat flow with respect to the layers or fibres of the material. For example, the λ -factor along the fibre is twice as much as that across it. Materials of similar porosity may have different λ -factors, depending on the pore size: the larger the pores, the higher the λ -factor. For a material of uniform structure, the value of λ -factor varies with its bulk density. The λ -factor is also influenced by the moisture content of a material, since moist materials have a better thermal conductivity than the dry. This is explained by the fact that water has thermal conductivity 25 times as high as that of air.

Materials used for outside building walls and ceilings should have a sufficiently low λ -factor to resist the heat flow through the walls.

Heat capacity is the property of a material to take up heat on heating and to give it off on cooling. Heat capacity is the amount of heat required to raise the temperature of material. Heat capacity related to a unit weight is known as *specific heat capacity* and, according to the SI system, it has the dimension: joule/kilogram degree Celsius ($J/kg^\circ C$).

Heat capacity is taken account of in calculations of heat

* Russian abbreviated notation will be Mps 10, and so on.

stability of walls and ceilings of buildings having central heating, and of the required warming of concrete and mortar components in winter. It is recommended that the materials of walls and ceilings of buildings with central heating have possibly the highest specific heat capacity.

Acoustic properties (transmissivity and absorptivity) of materials characterize their behaviour in acoustical environment, i.e. the rate at which various construction materials transmit or absorb sound waves. Acoustical treatments have become increasingly important in the design of buildings, especially of those with specified acoustical conditions.

Sound absorptivity of a material is described by its acoustic absorption coefficient expressed as a ratio of the sound energy absorbed by a unit surface to the total energy per unit time. The acoustical properties of materials depend upon their structure. Materials with passable pores are less reflective to sound than those with unpassable ones.

Sound transmissivity is the property of a material to transmit sound and is characterized by the coefficient of transmissivity, which defines the relative attenuation of sound intensity as it is transmitted through the thickness of material. Sound insulation is best provided by multilayer walls or partitions with alternating layers of porous and dense materials.

Fire-resistance. This is, as the word implies, the property of a material to resist the action of fire. By the fire hazard characteristics, construction materials are distinguished as nonburning, slow-burning and burning.

Brick, concrete and steel neither burn nor smoulder or char. The slow-burning materials (for example, fibrolite and asphaltic concrete), once inflamed, will smoulder or char until the exposure to the flame is ceased; the burning materials (wood, felt, ruberoid and tar paper) burn and do so after the source of flame is removed.

Refractory materials can resist, in varying degree, the action of temperatures as high as above 2 000°C.

Mechanical properties (strength, elasticity, plasticity, brittleness, hardness and durability) characterize the ability of materials to resist the destructive or deforming action of loads.

Strength is the property of a material to withstand the limiting stress without failing by rupture or continuous plastic flow.

In the SI system the unit for pressure or strain is the pascal

(Pa) or megapascal (MPa), the prefix "mega" indicating an increase in value of one million times. Pascal is the pressure exerted by a force of one newton over an area of one square metre. $1 \text{ MPa} = 10 \text{ kgf/cm}^2$.

Construction materials used in the components of a building undergo various stresses, so the strength of a material predetermines the stress that a given member can withstand at the specified cross section.

The strength of a material is characterized by its ultimate strength in compression, bending and tension. The ultimate strength of a material is the stress at which the material is destructed. The ultimate strength in compression or tension is determined by the following formula:

$$R_{c(t)} = P/S$$

where P is the breaking stress, N; S is the cross-sectional area of the specimen, m^2 .

The ultimate strength in bending, R_b , with a single concentrated load and a specimen beam of rectangular section, is defined by the formula:

$$R_b = 3Pl/(2bh^2)$$

where P is the breaking load, N; l is the span between the supports, m; b and h are respectively the width and height of the beam cross-section, m.

The ultimate strength of materials is determined experimentally on specimens of required shape, using testing machines.

Elasticity is the property of a material to deform under load and to return to its original shape when the load is removed. The maximum stress that the specimen can withstand, without undergoing permanent deformation, is known as *elastic limit*. Rubber, steel and wood are examples of elastic materials.

Plasticity is the ability of materials to remain deformed without elastic rebound or rupture after the load has been removed. This property is opposite to elasticity and is familiar in clay puddle and warmed bitumen.

Brittleness is the property to easily rupture under stress with little or no plastic deformation. Stone, ceramic materials, glass, cast iron, concrete and some other materials are referred to as brittle.

Hardness is understood as resistance of a material to the penetration of a harder solid. This is an important quality for materials used for flooring and pavements.

Hardness can be determined by several methods. So, hardness of metals and concrete is established by pressing a steel ball against the tested material, and the hardness is then judged by the depth or diameter of the impress left by the ball.

The usual hardness scale for rock and stone is Mohs scale of 10 minerals arranged in the increasing order of hardness, i.e. each mineral is scratched by the next of a higher grade (Table 2).

Table 2

Mohs Scale of Hardness

| Hardness index | Mineral | Description |
|----------------|----------------------|--|
| 1 | Talc or chalk | Easily scratched by the finger nail |
| 2 | Gypsum or rock salt | Scratched by the finger nail |
| 3 | Calcite or anhydrite | Easily scratched by a knife blade |
| 4 | Fluorspar | Scratched by a knife blade if slightly pressed against |
| 5 | Apatite | Scratched by a knife blade if strongly pressed against, does not scratch glass |
| 6 | Feldspar | Scratches glass slightly, but is not scratched itself by a knife blade |
| 7 | Quartz | Easily scratch glass, but are not themselves scratched by a knife blade |
| 8 | Topaz | |
| 9 | Corundum | |
| 10 | Diamond | |

The use of Mohs scale is as follows. Suppose that the material (mineral), the hardness of which is wished to determine, is scratched by No. 5 in the scale but itself scratches No. 4, then the required estimate of the hardness is between 5 and 4, i.e. 4.5.

Wear resistance of a material is its property to resist wearing away caused by abrasion. This quality, important for heavy-wear elements (floor, steps and pavements), is graded in the laboratory on abrasion-test machines.

Chemical properties of a material characterize its ability to chemical transformation under the action of the substance,

with which it is in contact. By way of example, cement interacting with water in the course of making concrete forms a tough cement stone, the main component of concrete. However, under the action of water containing sulphates, the concrete fails as a result of corrosion of cement stone.

The basic characteristic of a material is its resistance to corrosion, i.e. to the action of corrosive medium (water, gases, solutions of salts, acids, etc.). The corrosion-hazard characteristics of construction materials and anticorrosion measures are normally given in special regulations.

Chapter II

Natural Rock Materials

Rock is used as a raw material to make building products by mechanical shaping and polishing. The building materials thus obtained preserve (almost entirely) the physico-mechanical properties of the rock they are made of. The rocks have formed as a result of geological processes developing over millions of years. Rocks are basically a mass of mineral matter of one or more minerals. A rock consisting of essentially one material is known as *monomineralic* and that bearing several minerals as *polymineralic* rock.

A mineral is a natural substance formed as a result of physico-chemical processes taking place in the earth's crust. Each mineral is characterized by definite chemical composition and physico-mechanical properties.

2.1. Rock-Forming Minerals

There are known more than 2 500 minerals but only about 50 of them are known as rock-forming. Each mineral is described by its physical properties, such as density, hardness, strength, durability, pattern of cleavage, lustre, colour and others.

The building properties of rocks are determined by chemical composition of component rock-forming minerals and their physical properties. There now follows a description of properties of the main rock-forming minerals.

Quartz is a silicon dioxide (SiO_2), being a component of many minerals, constitutes about 12% of the earth's

crust. It is one of the most stable rock-forming minerals (density— $2\,650\text{ kg/m}^3$, hardness by Mohs scale—7, strength in compression—more than $1\,000\text{ MPa}$). Quartz melts at a temperature of $1\,710^\circ\text{C}$ forming, after rapid cooling, quartz glass. Quartz sand, widely used in construction, is formed by stable particles of quartz weathered from volcanic rocks.

Feldspars compose a group of the most widely spread rock-forming minerals that constitute about 60% of the earth's crust. They vary in colour from white to dark-red and have a density from $2\,500$ to $2\,760\text{ kg/m}^3$, hardness 6 and strength in compression from 100 to 170 MPa . The feldspars respond strongly to the atmospheric action and in the process of decomposition they form kaolinite—the basic component of sedimentary clayey rocks.

Micas form a mineral group of which biotite and muscovite are the most common. Biotite is nontransparent and dark, even black, in colour with characteristic metallic lustre. Muscovite is a transparent colourless mica. Micas are easily cleaved into flexible and clastic laminae or flakes, their density ranges from $2\,800$ to $3\,200\text{ kg/m}^3$ and hardness from 2 to 3.

A high mica content in a rock produces a sheetlike structure, reduces its strength and durability and hinders its polishing.

Ferro-magnesian minerals are dark in colour and are therefore called dark-coloured; their density ranges from $3\,000$ to $3\,600\text{ kg/m}^3$ and hardness from 5.5 to 7.5. Minerals of this group (olivine, augite, hornblende) are highly stable and resistant to the atmospheric action, thereby endowing the volcanic rocks that bear them with the same properties.

Calcite (calcspars) CaCO_3 is widely distributed in calcareous sedimentary rocks. It is a transparent and colourless mineral, but may be rose, blue, red, yellow, etc., the colour being determined by the impurities. It has a density from $2\,720$ to $2\,800\text{ kg/m}^3$ and hardness 3. Under the action of hydrochloric acid calcite will actively “boil” evolving carbon dioxide.

Magnesite—magnesium carbonite (MgCO_3)—is less spread than calcite. It is white in colour, often with yellow or greyish tinge, and has a density from $2\,900$ to $3\,100\text{ kg/m}^3$ and hardness 3.5 to 4.5.

Dolomite ($\text{CaCO}_3 \cdot \text{MgCO}_3$) is white in colour, often tinged with yellow, brown or red. Density— $2\,000$ – $2\,800\text{ kg/m}^3$, hardness 3.5–4. Dolomite may occur as extensive beds often

resulting from the replacement of calcite, also as alteration of limestone, or in other sedimentary rocks.

Gypsum—a mineral found in clays and limestones. By its chemical composition it is hydrous calcium sulfate, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. Pure gypsum is white, but may be grey, yellow or pink due to impurities. Its density is equal to $2\,300\text{ kg/m}^3$ and hardness to 1.5-2. Gypsum is noticeably soluble in water.

Anhydrite is anhydrous calcium sulfate, CaSO_4 . In appearance it resembles gypsum but has a higher density ($2\,800\text{--}3\,000\text{ kg/m}^3$) and hardness (3-3.5); as it absorbs water, it transforms into gypsum, with which it is often associated.

Kaolinite—the pure type is white in colour, but due to impurities may have yellowish, brown, greenish and other tints. Density— $2\,600\text{ kg/m}^3$, hardness 1-1.5. Kaolinite is the main mineral of many clays and kaolins.

Silica occurs in sedimentary rocks in the form of quartz (quartz sand and sandstone) or as opal, a hydrated amorphous variety of silica. Rocks bearing a great thickness of opal (for example, diatomite and tripoli) are widely used to make some compound binding substances.

2.2. Rocks Used in Construction

All rocks are classed, depending on their geological origin, into three types: igneous, sedimentary and metamorphic. The conditions of formation determine to a great extent the structure of a given rock type, which in turn determines the constructional properties of the rock.

Among the variety of rocks belonging to the groups mentioned above we shall deal with only those which are important for building purposes.

Igneous (volcanic) rocks have formed from solidification and crystallization of magma which on eruptions either reached the surface of the earth or was trapped in its crust where it cooled. By the conditions of the environment in which cooling and crystallization took place, the igneous rocks are distinguished as *plutonic* and *volcanic*. The volcanic rocks include also fragmental volcanic material (pyroclastic rocks) formed through the explosive activity.

Plutonic rocks have formed beneath the surface of the earth by consolidation of magma under considerable pressure of upper layers. Under such conditions plutonic rocks

obtained an equigranular texture (Fig. 1a) in which coarse grains of various minerals have grown together.

Plutonic rocks are characterized by a high density, durability, frost resistance and low water absorption. The main plutonic rocks are granite, diorite, gabbro and labradorite.

Granite. A coarse-grained igneous rock consisting essentially of quartz, feldspar, mica and other coloured minerals. It is found in a range of colours including reds and pinks, greys and browns. Granite has a density of $2\,700\text{ kg/m}^3$, porosity of 0.5 to 1.5% and strength in compression from 100 to 250 MPa. Granite is characterized by high resistance to frost and weathering and low water absorption. It can be

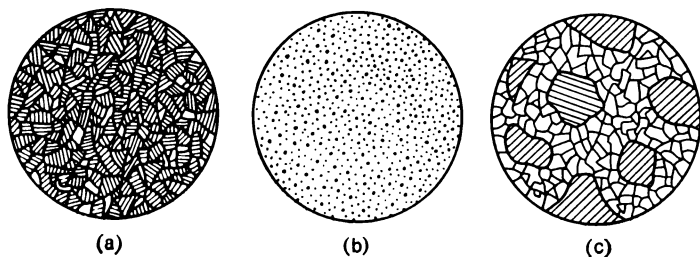


Fig. 1. Granular-crystalline (a), amorphous (b), and porphyritic (c) textures of rock

given a fine polish and is used as facing material for buildings, structures and embankments. Also, it goes to make curbstones, stair-tread pieces and other building units, and is an aggregate material for high-strength concrete.

Diorite consists essentially of feldspar and hornblende and varies in colour from grey to dark-green. Its density ranges from $2\,700$ to $2\,900\text{ kg/m}^3$ and strength in compression from 150 to 300 MPa. Diorite is characterized by a good impact strength and resistance to wear and weathering. Easy in polishing, it is used as paving and facing material.

Gabbro is the strongest and the most durable extrusive igneous rock consisting of feldspar and dark-coloured minerals. The gabbros are melanocratic, often with a greenish or greyish hue. They have a density of $2\,800$ to $3\,100\text{ kg/m}^3$ and strength in compression from 200 to 300 MPa. Gabbros are resistant to impacts and weathering.

Labradorite, a variety of gabbro, produces, when polished, an attractive surface with a play of blue, green and

other colours, and is used as decorative facing material.

Effusive (volcanic) rocks have formed through the cooling of lava, i.e. of magma extruded to the earth. The cooling and solidification of lava in the conditions on the earth's surface proceeded rapidly, which resulted in various degrees of crystallization. Depending on conditions of formation the effusive rocks may have a fine-granular (holocrystalline) or amorphous (glassy) texture (Fig. 1b); with a slow release of gas by the cooling magma the porous texture had developed. The density and strength of effusive rocks vary within wide limits. The chief effusive rocks widely used in building are basalt, porphyrites and diabase.

Basalt. Igneous rock with a density of up to $3\,200\text{ kg/m}^3$, dark-grey in colour. Strength in compression over 400 MPa, hard for shaping. Crushed basalt is widely used for building purposes, as well as aggregate material to make precast structural members.

Porphyrites are characterized by porphyritic texture, i.e. when larger crystals (phenocrysts) are set in a finer ground-mass (Fig. 1c). They are found in colours from reddish-purple to grey with various hues. They vary in density from $2\,400$ to $2\,500\text{ kg/m}^3$ and in strength in compression from 120 to 180 MPa. Porphyrites go to make facing tiles and are used in road building.

*Diabases**—analogues of gabbros—have a fine-grained texture and a dark grey colour, often with a greenish hue. Density— $2\,800$ – $3\,000\text{ kg/m}^3$, strength in compression—200–300 MPa. Diabases are hard, durable and impact-resistant; they are used for road coatings and as raw material to produce aggregate for precast structural members.

Pyroclastic rocks. Pyroclastic rocks consist of fragmental volcanic material which has been blown into the atmosphere by explosive activity. They are found either in unconsolidated state or as consolidated rock (where country cementing material was present). Volcanic ash and pumice are examples of unconsolidated rocks and volcanic tuff of consolidated ones.

Volcanic ash includes dustlike particles of lava. It has a glassy (amorphous) texture, in terms of chemical compo-

* In Great Britain basaltic rocks with ophitic texture are called dolorites, and the term diabase is restricted to the altered dolorites.
Tr. note.

sition silica and alumina are predominant. Fragments up to 5 mm in size form what is known as volcanic sand. Volcanic ash and sand are used as active admixtures to cement.

Pumice. A highly vesicular, froth-like material of light grey colour. Its density varies from 400 to 600 kg/m³, strength in compression is about 5 MPa. Pumice is used as an aggregate for light concrete.

Volcanic tuff. Consolidated volcanic dust and sand form volcanic tuff. Great variation of colour is seen, but green, grey and buff are common. Tuffs are quite vesicular, have low density (800-2 000 kg/m³) and thermal conductivity. They are strong, durable and easily workable, and are used as local material for walls or as outside facing of buildings. The material remaining after treatment of tuff is used as an aggregate for light concrete.

Sedimentary rocks. These, often referred to as *secondary* rocks, have formed from material derived from the pre-existing igneous rocks by processes of denudation, together with material of organic origin. The term includes both consolidated and unconsolidated material. They are classified, on the basis of the character of the material and the processes which have led to their deposition, as *clastic*, *organic* and *chemical*.

Clastic deposits (fragmental) have formed through the destruction of igneous and other rocks due to sharp variation of temperature, weathering and erosion. They are composed of fragments of pre-existing rocks (sand, gravel, clay). Sometimes loose deposits were cemented by natural substances forming solid rocks: sandstone, conglomerate and breccia, which find wide application in construction work.

Sand is a loose mixture of various mineral grains ranging in size from 0.14 to 5 mm. By their composition, sands may be distinguished as quartz, feldspar, limestone, pumice and other types. Sand is used as an aggregate for mortars and concretes.

Gravel. Accumulation of rounded fragments of rock with a diameter range from 5 to 70 mm. In construction, gravel is used as an aggregate for concrete and asphalt concrete.

Clays are finely fragmented rocks consisting of very fine particles of kaolinite, montmorillonite and other minerals, and of particles of quartz, mica, feldspar, etc. Clays are used in the manufacture of ceramic materials and cement.

Sandstones. Cemented or otherwise compacted detrital sediments composed predominantly of quartz grains. Accord-

ing to the nature of the binding or cementing material, argillaceous, siliceous and calcareous varieties are recognized. Physico-chemical properties of sandstone depend on the composition of cementing material, size and shape of the cemented grains. Sandstones may be of yellow, grey and other colours. Siliceous sandstones are the strongest, their density is from 2 500 to 2 600 kg/m³ and compressive strength, 150-250 MPa. They are also highly resistant to wear. Sandstones are used in construction as rough stone and flooring material for industrial buildings and pavements and other applications.

Conglomerate and breccia. Conglomerate consists of rounded to sub-rounded cemented pebbles; angular to sub-angular pebbles are types of breccia. The strength of these rocks depends on the strength of component rocks and cementing material. They are used in construction as rough stone and aggregate.

Chemical sedimentary rocks are formed through the precipitation of mineral matter from true and colloidal solutions with their subsequent compaction and cementation. They include dolomite, magnesite, gypsum and anhydrite.

Dolomite is a monomineralic rock used in the manufacture of facing tiles and as aggregate for concrete and binding material.

Magnesite consists essentially of the mineral of the same name and is used in the manufacture of binding and refractory materials.

Gypsum is a dense rock consisting of the mineral of the same name and finds application as raw material to produce construction gypsum.

Anhydrite in appearance and physical properties resembles gypsum, but is rarer in occurrence than the latter. It is used for inside facing of buildings and to make anhydrite cement.

Organic sedimentary rocks are deposits resulting from the remains of organisms and plants whose shells and skeletons consist of mineral substances. Such deposits are, as a rule, consolidated. Organic rocks that find application in construction are limestone, shell limestone and chalk (which consist essentially of CaCO₃), tripoli and diatomite.

Limestone is a widely distributed rock consisting essentially of mineral calcite. Its colour is determined by admixtures, so pure limestone takes a yellowish tint due to clay. The rock composed of mixture of limestone and clay is known as marl.

Limestones may be compact or porous, with the density varying from 1 800 to 2 600 kg/m³ and compressive strength from 60 to 150 MPa. The dense limestones are used to manufacture tiles and stones for exterior applications, concrete aggregate, lime and portlandcement.

Shell limestone is a porous rock consisting of shells and fragments and binding lime. It is characterized by high porosity, but its bulk density, strength and thermal conductivity are low. Shell limestone can be sawn and is easily workable.

Shell limestones ranging in density from 1 000 to 1 500 kg/m³ are used to make stones and blocks for house construction, and the waste material is used as an aggregate for light concrete.

Chalk. A very soft, white in colour, undurated limestone composed of the tests of floating microorganisms. It is used as white-colouring agent in manufacture of paints, pastes, lime and portlandcement.

Diatomite and tripoli. Light, incoherent siliceous rocks composed of the shells of diatoms, rounded particles of opal, trustules of diatoms and radiolarian skeletons. The rocks are used to make thermal-insulation materials and as active admixtures to cements.

Metamorphic (changed) rocks have formed from igneous and sedimentary rocks in response to pronounced changes of temperature, pressure, and chemical environment. Under the action of these factors, recrystallization of mineral matter in the solid state took place, resulting in a higher density of the formed rock in comparison to the original rock. As a rule, the metamorphic rocks have a foliated structure, but the structure of the original rock may also be preserved. Metamorphic rocks used in construction are marble, quartzite, and gneiss.

Marble is a rock of granoblastic texture formed by the recrystallization of limestones, dolomites under the action of high temperatures and pressures. Pure varieties of marble are white, but admixtures may lend them pink, red, grey, or black colours, as well as attractive decorative colour patterns.

Marble is characterized by a high density and strength; its density reaches 2 800 kg/m³, moisture content is within 0.7%, and compressive strength ranges between 100 and 300 MPa. Hardness of marble is not high (3-4), therefore it can be easily cut into thin slabs, ground and polished.

Marble is used for interior facing of walls, to manufacture step units, window sills, and other structural members which are mostly used in public buildings and installations. The waste marble (small particles) goes to produce mosaic concrete units. Marble should not be used for exterior facing as it rapidly loses its decorative features under the action of atmospheric gases and moisture.

Quartzite is a variant of silicious sandstone, white, light grey, dark grey, or reddish brown in colour. Quartzite is dense, tough, and friable and is highly resistant to weathering. Its density is from 2 500 to 2 700 kg/m³ and compressive strength is up to 400 MPa. Quartzite is used as dressed stones or slabs for exterior facing of important parts of buildings and installations, and as aggregate for concrete.

Gneisses are close in composition and physical properties to original granites, but differ from them in banded or schistose structure. They are of light or variegated colour, and are alike with granites in applications.

2.3. Building Stone

The methods of mining for building stone materials depend on the mode of their occurrence, strength, hardness and the shape of the meant products. The igneous rocks that crop out or have a shallow occurrence are excavated in quarries by the open-cut method and those of deep occurrence are produced by underground mining.

Tough rocks used to produce aggregate or rough stone are excavated by the explosion method. Stone slabs or blocks are produced from large rock pieces cut out by stone-sawing or stone-cutting machines, and other equipment.

Easy-workable rocks such as tuff or shell limestone are fractured by stone-sawing machines equipped with horizontal and vertical disc-type saws carrying changeable cutters.

Incoherent rocks (sand, gravel, clay) are excavated by open-cut method using various machines.

Treatment of stone. Separated lumps of rock undergo required treatment, i.e. they are given the specified shape, size and texture. For this purpose stationary and portable machines, and diamond cutting tools are used.

Types of stone units. *Quarry or rubble stone*, as used in construction, comes as lumps or thin slabs of rock of irregular shape. The weight of separate stones is within 20-40 kg.

Rubble should have compressive strength of at least 10 MPa and a wet-to-dry strength ratio of 0.75. It should also be sorted out to meet the constructional requirements.

Rubble is used for walls and formations of buildings and structures that have no heating systems, and retaining walls, etc. Crushed material is used as aggregate for concrete.

Wall stones and blocks are made from limestone and volcanic tuffs and other rocks with a bulk density of up to 2 300 kg/m³. Stone for hand-laying is in size 390 × 190 × 190 mm, the size of blocks for mechanized laying is determined by the strength of rock and lifting capacity of the available cranes.

Wall blocks of 780 mm and over in height should have slots on the two side faces, 50-70 mm deep. The slots can be rectangular, triangular, semicircular, or tapered in section.

Stones and blocks are, as a rule, shaped by stone-sawing machines, their faces may have decorative patterns (Fig. 2).

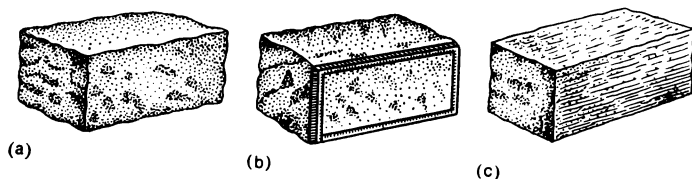


Fig. 2. Stone blocks

(a) rough hewn; (b) dressed and (c) sawn

Rock used to make wall stones and blocks should have an ultimate compressive strength of not less than 2.5 MPa, frost resistance of 15 freeze-and-thaw cycles, and a wet-to-dry strength ratio higher than 0.6.

Natural stones and blocks, as construction materials, cost far less than brick and are attractive in appearance.

Facing stones and thin slabs are made of natural stone by sawing or breaking followed by mechanical treatment. Rocks used as exterior facing material (granite, sienite, gabbro, labradorite, quartzite, tough limestone, etc.) must be resistant to the atmospheric action and meet the strength and decorative requirements. The facing stone or slab can be given, besides polished and rubbed finishes, various textured finishes such as hand-tool finishes, sawed finishes, and machine-tool finishes.

Stones and slabs made of granite, labrodite and gabbro are used to face columns, plinth walls and facades of monumental buildings, and as flooring material in public buildings and structures where intensive wear is expected (underground and railway stations, department stores, etc.). Figure 3 gives an example of combining rough-finished granite stone (imitating natural appearance) with that of polished finish.

For interior of monumental buildings, marble slabs 8-12 mm thick with lustre finish are used.

Natural stone is also used to make shaped units such as plinths, quoins, cornices, steps and window sills, etc.

Materials and units for various purpose. These include various units used in road construction, such as paving blocks, hewn stone, curbstone, etc. For such units, tough and durable rocks (igneous or sedimentary) with low water absorption and good impact resistance, are used.

Transportation and storage. Care should always be taken to protect building stone from mechanical damage, dirt or moisture. The cut stones, as transported, should be arranged on the edges and separated by spacers. For polished stones special containers are used with the polished faces arranged inside and separated by paper. Facing materials stored indoors or outdoors should be sorted out to types. The curbstones are kept outdoors arranged on wooden mats. The storing area should be provided with an adequate sewage.

Weathering protection. The stone material of buildings undergoes the destructive action of atmospheric environment, which is termed weathering (in analogy with rock weathering). The main destroying agent is rain water filling the cracks and pores of stone which, when freezed, expands and breaks the surface of the material. Sharp changes of temperature cause the microcracking of the surface and crumbling of the stone. The chemical action of gases in air also



Fig. 3. Granite-slab facing of an office building

affects the stone, for example, that of sulphur dioxide on limestones and marbles.

The stone of a building can be protected by providing fast drainage of water from the stone surface and a polished finish of the stone face.

Building units made of carbonate rocks can be effectively protected by fluating, i.e. by impregnating their surface with fluates, which reacting with calcite (CaCO_3) form an insoluble compound that fills the pores, thereby preventing penetration of water.

Generally, the building units made of rock are advised to be covered with water-repelling coating.

Chapter III

Ceramic Materials

3.1. Raw Material for Ceramics

Ceramic materials are made of clays or their compounds with mineral additives by the processes of moulding and baking. The ceramics as building materials have many virtues: the raw materials for their production are abundant and can be given any shape. The baked building units are hard and enduring.

Clays. Clay is a natural substance of soft rock which, when finely ground and mixed with water, forms a pasty, moldable mass (puddle) that preserves its shape when air-dried and becomes stone-like on cooling after burning.

Clays differ in particle size and, consequently, in their properties. Clays contain a significant amount of particles (mainly of kaolinite) smaller than 0.005 mm, which are referred to the clay grade. These particles are responsible for plastic properties of clays. Particles ranging in size from 0.005 to 0.15 mm are of the silt grade and those from 0.15 to 5 mm of sand grade. Silt and sand particles are not plastic. However, sand is a useful admixture as it forms in the clay mass what can be taken as a skeleton, and reduces shrinkage of clay in drying and burning.

In accordance with the content of clay-grade particles, the following clay rocks are distinguished: heavy clay (more than 60%), common clay (30-60%), silt clay (10-30%) and loamy sand (5-10%).

Important factors in the manufacture of ceramic materials are the plasticity of clay, air and heat shrinkage, refractoriness and colour of the finished unit.

Plasticity. The property of a clay puddle to take under a load the required shape without rupture and preserve it when the load is removed. Plasticity of clays depends on the mineralogical composition, size and shape of particles, etc. An increase in the amount of clay grade particles will add up to the plasticity of clay. Highly plastic (fat), medium and low plastic (lean) clays are distinguished.

Air-drying of a clay sample is characterized by its shrinkage in the course of drying. Shrinkage is expressed as a percentage of the original size of the sample. Highly plastic clays have an air-drying shrinkage in excess of 10%, medium-plastic from 6 to 10% and low-plastic less than 6%.

Fire-shrinkage of the dry sample takes place in the course of its burning, normally it is within 1-4%. Total shrinkage is a sum of the air (drying) shrinkage and fire-shrinkage and is usually found between 5 and 18%, with the higher values related to highly plastic clays. Intensive shrinkage of clay may result in deformation of a unit (bending, cracking and so on).

Refractoriness is the ability of clay to withstand high temperatures without deformation. Depending on the temperature of softening clays can be distinguished as refractory (over 1 580°C), high-fusing (1 580-1 350°) and low-fusing (below 1 350°).

Refractory clays are used to make refractory units, porcelain-ware and earthenware. High-fusing clays find application in the manufacture of flooring tiles, sewage pipes and other types of construction ceramic units. Low-fusing clays go to make clay brick, roof tile, hollow-ceramic units, etc.

The colour of a burnt clay unit depends on the composition and content of admixtures present in the clay. Kaolin is the purest material, items made of it are white. Iron oxide present in clay produces colours from light yellow to dark red; variation in colour and hue of ceramics can be attained by introduction of natural pigments.

Leaning and burning admixtures. Fat clays of high plasticity are seldom used in their pure state in the manufacture of ceramics, since they will shrink on drying and burning to the extent causing deformation. To reduce shrinkage, leaning agents (sand, crushed slag, ash of solid fuel, finely

fragmented ceramic breakage and crushed burnt fireclay) are added to the raw material.

To achieve lighter ceramics of higher porosity and lower thermal conductivity, the raw clay is admixed with pore-forming agents (sawdust, coal powder, peat, etc.) that burn out in the course of baking.

3.2. Wall Materials

The common clay brick are manufactured from low-fusing clay, using the plastic (wet) and dry methods.

The common brick are made of clay run from the pits, usually closely located to the brick-making plant. The plastic

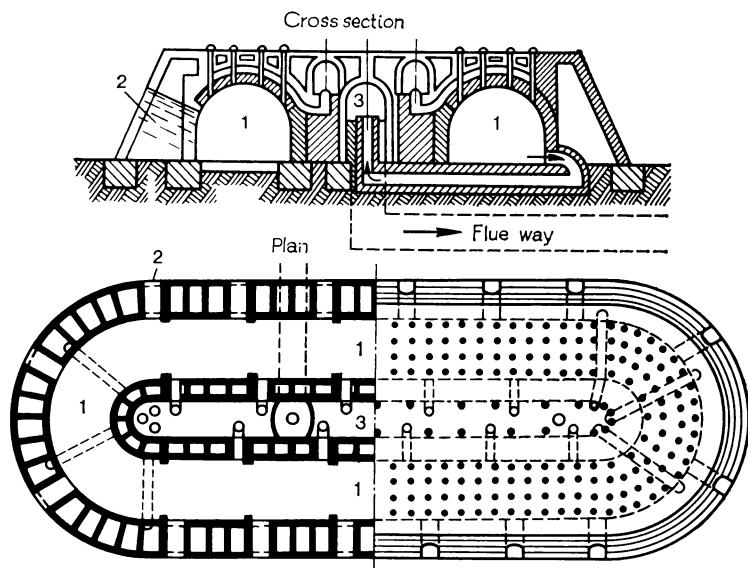


Fig. 4. Circular kiln

1—kilning channel; 2—brick loading or unloading openings; 3—central flue gases exhaust

method consists in preparation of raw material (clay slip), formation of brick, and drying and burning operations.

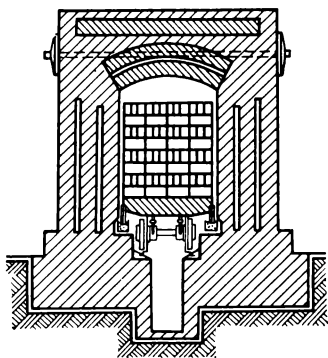
To prepare clay slip, raw clay is ground by the rollers until fine-ground, then it is tempered in a pug mill where its mois-

ture content is raised to 18-25%. Next, the raw material is stirred to become a uniform mass ready for shaping.

Clay brick are formed on brick-pressing machines (vacuum presses), in which the clay slip is densened and part of its air content is pressed out, which improves the quality of the brick. A single vacuum press can handle about 10 000 brick units per hour.

The formed (raw) brick are dried in natural conditions (drying premises) for 8-15 days, or for 2-3 days if warmed air is used. The dried brick are burnt in circular- or tunnel-type continuous kilns.

The circular kiln of Fig. 4 is an oval-shaped kilning flue arbitrarily divided into chambers. The number of chambers ranges from 16 to 36, depending on the capacity of the kiln. The chambers are zoned in accordance with the brick-processing stages: charging (raw brick), pre-heating, burning, cooling and discharging (burnt brick) from the kiln. In the circular kiln the source of fire and other zones are moving continually along the kilning channel, while the brick in process remains stationary. The burning cycle takes 3 or 4 days at the kiln temperatures of 900-1100°C.



[Fig. 5. Tunnel kiln

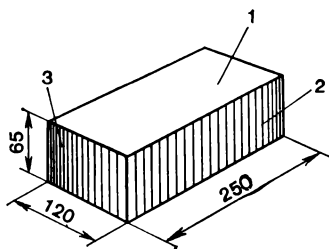


Fig. 6. Common clay brick
1--bed; 2--face; 3--end

The tunnel kiln of Fig. 5 has a kilning channel 100 m long, in which brick-loaded trollies move over a track passing by the stationary operational zones. The tunnel kilns are more economical than the circular ones and allow for automatic control of the process.

With the dry press process, clay brick is formed from clay powder. The resulting raw product has the specified size and is strong enough to undergo the drying and burning processes.

Properties. Common clay brick is made in ordinary size $250 \times 120 \times 65$ mm (Fig. 6) and modular size $250 \times 120 \times 88$ mm (cores are specified). Variation from the specified size should be: ± 4 mm in length, ± 3 mm in width, $+3 -2$ mm in thickness for plastically pressed brick, and respectively ± 3 , ± 2 , ± 2 mm for dry-pressed brick. Brick must have the shape of a prism and regular smooth faces, sharp edges, and perfectly square corners. Minor imperfections (dull edges or corners, etc.) can be neglected if they are tolerable, but lime inclusions leading to breakage of brick are intolerable.

Holes in core brick, through or blind, are as a rule arranged perpendicularly to the bed face. The diameter of round holes is normally within 16 mm and the width of rectangular openings within 12 mm. For a dry-pressed brick with 8 blind cores the diameter of a hole should be within 45 mm and that for a unit with 18 through holes, 18 mm. The rows of holes in core brick should extend through the beds from at least 15 mm from the bed edge.

Underburned brick is red in colour and has a lower density and frost resistance, but overburned brick is hard and durable and has a relatively high thermal conductivity.

Table 3

Grades of Common Clay Brick

| Grade | Ultimate strength, kgf/cm ² | | | | | |
|-------|--|---------------------------------|--------------------------------|---------------------------------|----------------------------|---------------------------------|
| | compressive strength for plastically and dry-pressed brick | | for brick under bending stress | | | |
| | | | plastically pressed | | dry-pressed | |
| | average of 5 samples | minimum for single sample | average of 5 samples | minimum for single sample | average of 5 samples | minimum for single sample |
| 300 | 300 | 250 | 44 | 22 | 34 | 17 |
| 250 | 250 | 200 | 40 | 20 | 30 | 15 |
| 200 | 200 | 150 | 34 | 17 | 26 | 13 |
| 150 | 150 | 125 | 28 | 14 | 20 | 10 |
| 125 | 125 | 100 | 25 | 12 | 18 | 9 |
| 100 | 100 | 75 | 22 | 11 | 16 | 8 |
| 75 | 75 | 50 | 18 | 9 | 14 | 7 |

Bulk density of dry brick ranges from 1 600 to 1 900 kg/m³ and coefficient of thermal conductivity from 0.74-0.87 W/m °C. These properties of brick depend on the manufacturing technique. Brick made by dry press process will have higher density and thermal conductivity.

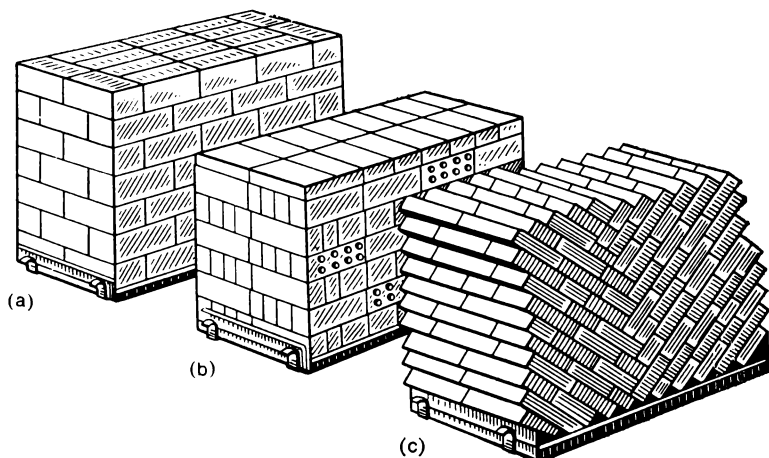


Fig. 7. Recommended arrangement of brick on trays
(a) multi-hole brick; (b) dry pressed, with 8 holes; (c) common clay brick

Clay brick are also graded with respect to their ultimate compressive and bending strength. The grades are given in Table. 3.

Water content of brick dried to a stable mass should make at least 6% for grades higher than 150 and 8% for other grades. Smaller values of moisture content are an indication of undesirably high thermal conductivity.

Transportation. Various types of brick are normally delivered to construction sites stacked on trays of standard size. The recommended arrangements of brick in stacks are given in Fig. 7.

Usage. Common clay brick is used for outside and inside walls and in other structural parts where harder and more durable materials are preferred. It is also used for brick panels.

Dry-pressed common clay brick is never used for outside walls in humid environment, and plinth walls and foundations below the hydro-isolation layer.

The modern practice is to use, instead of common brick, ceramic materials which, despite of lower density and thermal conductivity, are hard enough to meet the requirements. These are brick and block made with admixtures of tripoli and diatomite, and core brick.

Units made with admixtures of tripoli and diatomite by plastic or dry-press processes are relatively lighter and come as solid or cored. The ordinary brick size is $250 \times 120 \times 65$ mm, modular brick size— $250 \times 120 \times 88$ mm and of block— $250 \times 120 \times 138$ mm. Three density grades are distinguished: A—700-1 000 kg/m³, B—1 001-1 300 kg/m³, and C—above 1 300 kg/m³. Strength grade markings are: 75, 100, 125, 150 and 200.

These types of building units can be used for outside and inside walls of buildings in dry to humid environments. They should not be used for foundations, plinth walls and smoke flues.

Plastically pressed brick and block come as cored or porous-and-cored (of increased porosity) (Figs. 8 and 9). The increase in porosity is gained by adding of burning agents.

Core brick is manufactured in the following sizes: normal $250 \times 120 \times 65$, thickened $250 \times 120 \times 88$ and modular $288 \times 138 \times 65$ mm; cored block in sizes: normal $250 \times 120 \times 138$, modular $288 \times 138 \times 138$, oversize $250 \times 250 \times 138$, and oversize modular $288 \times 288 \times 138$ mm.

Density grades of cored and porous-and-cored brick and block are as follows (kg/m³):

| | A | B |
|-----------------|-------------|-------------|
| Brick | up to 1 300 | 1 300-1 450 |
| Block | 1 350 | 1 350-1 450 |

Strength grades are: 75, 100, 125, 150, 200 and 250. Water absorption of brick and block dried to stable mass should be not less than 6%; frost resistance, like that of common brick, i.e. 15-50 cycles.

Plastically formed brick is used for exterior and interior walls, non-load-bearing walls, and for large wall blocks and panels.

Face brick are rectangular (prism) or specially shaped units used in the exposed face of a wall. Their face surface may be smooth, form-rolled or textured. The more common colours of face brick are various shades of brown, red, grey,

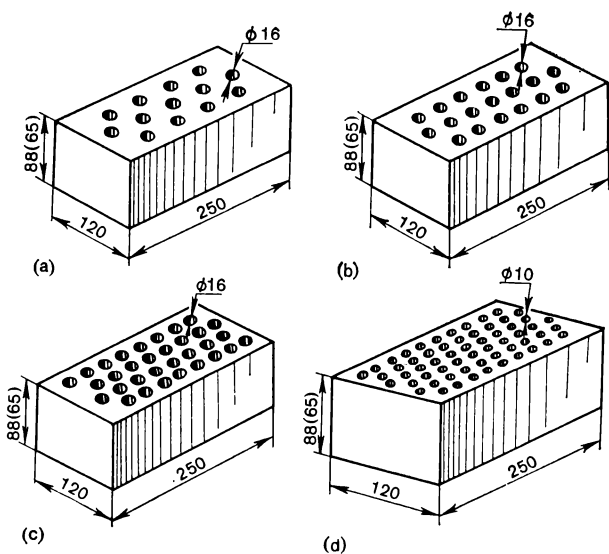


Fig. 8. Plastically pressed core bricks with (a) 13, (b) 19, (c) 32 and (d) 78 holes

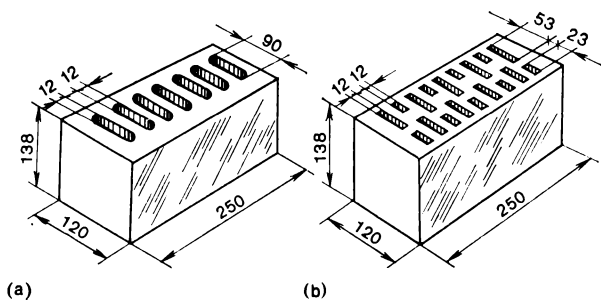


Fig. 9. Core blocks with (a) 7 and (b) 18 openings

yellow, and white. They come as solid or cored units, and are formed, as common clay brick, while they are plastic or half-dry. The texture of the face surface is produced by guniting, moulding (double layer), engobing, and form-rolling processes, using mineral chips.

The rectangular face brick is used for even parts of walls, and the shaped brick for cornices, belt courses, etc. (Fig. 10).

Moisture absorption of face brick should be from 6 to 14% and frost resistance 25-50 cycles.

Facing tiles are made of clay by plastic and dry-press processes and burned in tunnel kilns. They come in rectangular and square shapes, with sizes varying in length from 46 to 292 mm, in width from 21 to 292 mm, and in thickness from 4 to 10 mm. Moisture absorption is within 8% and frost resistance—50 cycles.

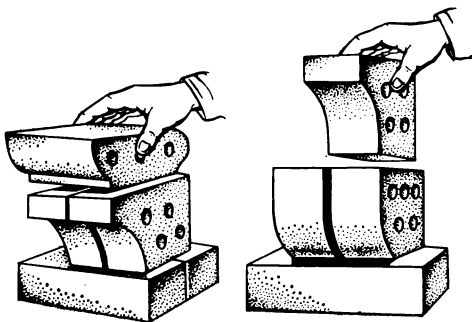


Fig. 10. Combinations of shaped brick

One surface of tiles is either smooth or relieved, or glazed and coloured (Fig. 11). The bedding face is indented to provide a reliable bond with mortar. The facing tile is used as facing material for exterior walls of buildings, plinth walls, walls of underground passages and vestibules, and for stairway lands, etc.

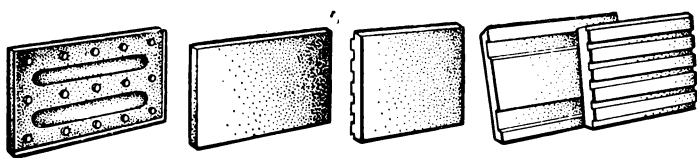


Fig. 11. Facing tiles

Facing tile from size $150 \times 75 \times 7$ mm and down are used to manufacture carpets, which are tiles combined into colourful patterns and glued face down to the craft-paper. The tile breakage of various colour is used to produce a breccia pattern. Wall blocks and panels are faced with ceramic carpets while they are formed.

Care should be observed in haulage and storage of facing tile. They should be well-packed and protected from mechanical damage, ceramic carpets should also be protected from moisture penetration.

3.3. Ceramic Floor and Wall Tile

Glazed floor tile and ceramic mosaic tile are widely used as flooring and facing materials.

Glazed face tile are manufactured from fire clay admixed with quartz sand and other mineral ingredients by the dry press process. After drying, tile is glazed and burned. Owing to glazing (white or of other colour) tiles obtain attractive appearance and become waterproof, and can resist the action of weak alkalis and acids. To provide a good cohesion with mortar, the back face of tile is made rough.

Tiles for interior facing come as square-, rectangular-, or fashion-shaped in sizes 150×150 , 150×100 and 150×75 mm, and thickness 4-6 mm. This type of tile is produced to meet high quality requirements and is particularly suited for walls or partitions in hospitals, food shops, dairies, laboratories, underground stations and other places where cleanliness and ease of cleaning is necessary (Fig. 12).

Mosaic facing tile is made by moulding process, in which porous ceramic moulds (moved by a conveyor-belt) are filled with the clay slip and coated with glaze. The porous moulds absorb water from the slip which is then cut into tiles, dried and burned.

The shapes of tiles are square or oblong: 50 mm, square, and oblong tile in $25 \times 100 \times 2.5$ mm and other sizes. The glazed tile is offered in a wide range of colours and textures. They are supplied in a mosaic sheet of tile, using a paper backing. Such sheets are used for interior applications and as facing material in the manufacture of panels.

Ceramic floor tile are made of clay, applying the leaning and colouring agents, by the same processes as are used in the manufacture of other fire clay products.

Ceramic floors are hard, waterproof and resistant to wear, acid- and alkali-proof, and convenient in maintenance. Their disadvantages are high heat absorption, low impact resistance, and high labour input.

With respect to the size, large-size and small-size (mosaic) tile are distinguished.

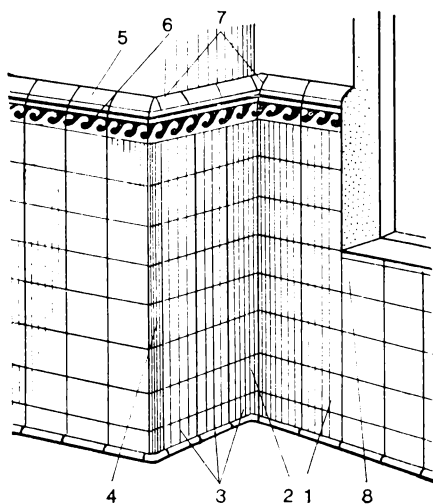
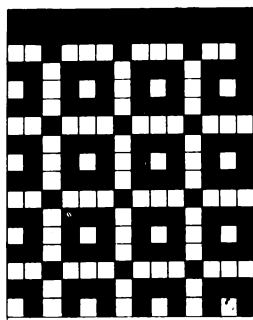
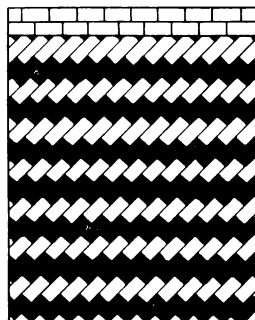


Fig. 12. Facing walls with glazed tiles

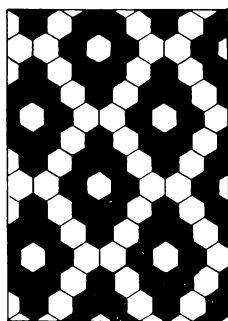
1—square tile; 2—inner angle; 3—skirting angles; 4—outer angle; 5—cornice tile; 6—belt; 7—cornice angles; 8—tile with a bent side



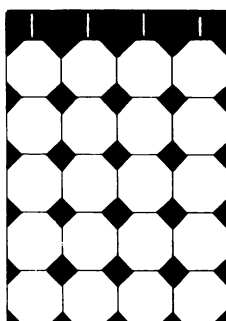
(a)



(b)



(c)



(d)

Fig. 13. Ceramic floor patterns

Large-size tile is made in many shapes (square, rectangular, triangular, hexagonal, etc.) and a range of sizes (length of the side) from 50 to 150 mm, with a thickness of 10-13 mm. The face of tile can be made smooth, rough or stamped, and in various colour patterns.

Ceramic floor tiles are bonded to their base floor by standard cement mortar or bitumastic. Various ceramic floor patterns arranged from large-size tiles are given in Fig. 13.

Mosaic tile is made in square and oblong shapes with the side size of 23 and 48 mm, 6 and 8 mm thick. They come in white, yellow, red, grey and other colours. Commonly they are supplied in a patternly-arranged square sheet of tile fixed to a craft-paper backing with a soluble glue. The advantage of mosaic tile is in the relative ease of its application and in the less-skid surface it produces owing to a closer mesh of tile joints.

3.4. Miscellaneous Ceramic Materials and Units

In this Section we shall deal with such ceramic materials as roofing tile, pipes, acid-proof units, hygiene equipment, heat-insulating and refractory materials and units.

Clay roofing tile are made by moulding, drying and baking processes, and come in various styles: grooved, flat, and ridged (Fig. 14). Roofing tile is hard, durable and fireproof. Roofs made of tile are easy in maintenance, but are heavy and difficult to install, and require significant sloping for drainage of rain water. Clay roofing tile are mainly used for cottages.

Sewer pipes are made of fireclay and high-melting clays. They are formed with hubs on special machines; after drying, the inner and outer surface of pipes are covered with glaze, which forms, in the course of baking, a thin, glass-like coating. This glaze coating renders sewer pipes waterproof and resistant to chemical action. The sewer pipes come in diameters (inner) from 150 to 600 and lengths from 800-1 200 mm and are used for sewage containing acids and alkalis.

Drain pipes are made of common clay and come in lengths of up to 500 and internal diameter 25-250 mm. The drain pipes have a smooth internal surface and sufficient mechanical strength, and are used for drainage of marshland and to reduce the ground water level under buildings and structures.

Acid-resistant units. These include acid-resistant brick and pipes, and acid-and-heat resistant tile, which are capable, as the name implies, of resisting continuous action of acids and alkalis. The acid-resistant units are of higher density, strength and thermal stability, as compared to the non-resistant ones.

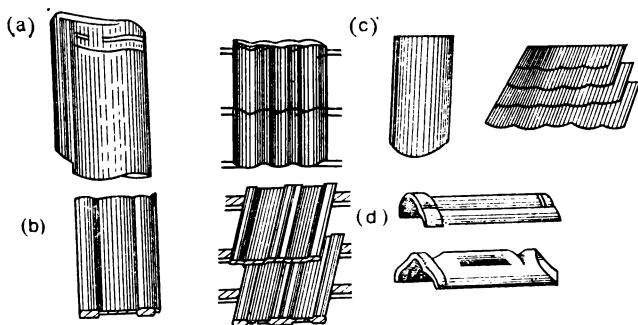


Fig. 14. Clay roofing tile
(a) and (b) grooved; (c) flat; (d) ridged

Acid-resistant brick are available as prism- or wedge-shaped and are used for foundations of chemical equipment and as lining material in chemical and other industries.

Acid-resistant tile come in square, rectangular and tapered shapes with the size of the side 50-200 and thickness—10-50 mm and are used for similar purposes. Heat-and-acid resistant tile is also used for lining digesters.

Acid-resistant pipes have internal and external surfaces glazed and are used in chemical industry for transportation of acids.

Sanitary equipment (sanitary ware) is essentially made of china or semiporcelain mass consisting of kaolin, fire clay, quartz, by moulding, drying and glazing processes.

Heat-insulating materials. Of broad variety of ceramic heat-insulating materials we shall deal only with expanded clay aggregate. This is a material composed of gravel-size, or less, particles of clay, and obtained by burning low-fusing clays capable of bloating under fast heating to 1 050-1 300°C. Gases that evolve as the original raw material is decomposed act as bloating agents.

Quality of expanded clay aggregate is characterized by its grain size, bulk weight and strength. Depending on the grain size, the following grain fractions are distinguished:

5-10, 10-20 and 20-40 mm (Fig. 15). Bulk-weight grades range from 150 to 800 kg/m³. For instance, if bulk weight of an expanded clay aggregate is 301-350 kg/m³, then it is specified as Grade 350. Compressive strength of the aggregate is 6-55 kgf/cm².

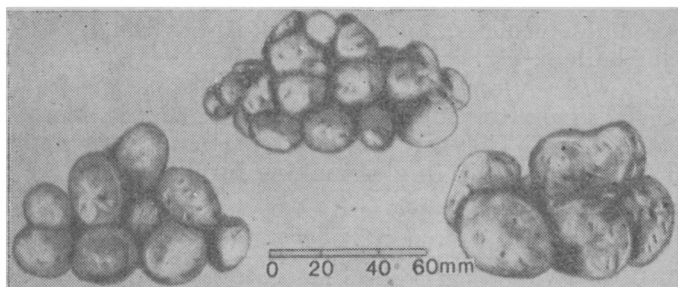


Fig. 15. Expanded clay aggregate

Expanded clay aggregate is used as insulating screens and filling material for light-weight concrete.

Refractory materials (refractories) are characterized by their ability to resist mechanical or chemical action in industrial conditions under temperatures over 1 500°C. By the heating limit they are distinguished as refractory (1 580-1 770°C), highly refractory (1 770-2 000°) and superrefractory (above 2 000°C). Refractories come as brick, block, tile and other shapes.

Among the refractories now in use are silica, aluminosilicate, magnesite, chrome, and silicon carbide refractories of which silica and aluminosilicate are most commonly used in construction.

Silica refractories are made of either quartzite or sandstone, or quartz sand with admixture of clay. They do not fuse below 1 710-1 750°C. Silica refractories are used for laying and lining of open-hearth, electric, glassmaking furnaces and coke ovens, which undergo simultaneously the action of high temperature and load.

Aluminosilicate refractories are produced from fire-clays and kaolins leaned with chamotte or various quartz admixtures. Depending on the content of SiO₂ and Al₂O₃ in the burned product, the semiacid, chamotte and high-alumina refractories are distinguished.

Semiacid refractories are made essentially of natural lean clay and are capable of resisting temperatures as high as 1 610-1 710°C. These are used for lining of blast cupolas, coke ovens and casting ladles, etc.

Chamotte refractories (1 710-1 730°C) are made of mixture of fire-clay and chamotte, and are also alkali-resistant. They are used for laying blast furnaces, walls and hearth of ceramic furnaces, and for brick-lining the furnaces of steam boilers, etc.

High-silica refractories (1 770-2 000°C) are made from raw material (bauxite, corundum, etc.) containing more than 45% of Al_2O_3 . They are durable, slag- and glass-resistant, and find application in glassmaking furnaces.

Chapter IV

Glass

4.1. Structural Glass

Glass is an isotropic and brittle material obtained from the supercooled liquid mineral melts. Basic raw materials for manufacture of glass are pure quartz sand, limestone, dolomite, soda ash, and sodium sulphate.

The glassmaking process includes the following operations:

- preparation of raw materials (concentration, drying and crushing);

- preparation of mixture (mixing of ingredients and briquetting);

- heat-processing of the mixture in the furnace at 1 400-1 500°C;

- molding a product from the melt;

- thermal, mechanical and chemical treatment of glass (to give it the required structural properties).

Glass has a high compressive strength (600-1 200 MPa), but its ultimate tensile strength is relatively low (30-50 MPa), with a hardness figure of 5-7.

Characteristic feature of glass is its high transparency, it transmits no less than 84% of visible radiation.

Glass has a low thermal stability, i.e. under sharp heating or cooling stress levels may become sufficient to cause cracking. Glass is resistant to chemical action.

Sheet glass comes in the following types: window glass, plate glass, wire glass, patterned, and heat-absorbing glass.

Window glass is unpolished glass, the most common in construction. It comes as sheets in sizes from 250×250 to $2\,000 \times 2\,200$ mm and 2-6 mm thick, with visible-radiation transmission of 84-90%. It is mounted in frames of wood, metal or plastic.

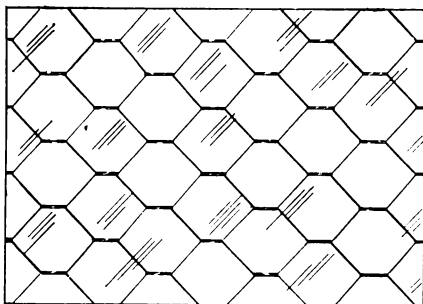


Fig. 16. Wired glass

Reflecting glass is commonly used to reduce the solar heat gain and transmission of light. It comes in the "gold" and "silver" types. The chrome-coated glass has a silvery tint on the outside surface and is transparent, if viewed from the room in the day-time, and it may be used in combination with common glass to produce multiple glass units.

Heat-absorbing glass is made by adding materials to the glass which absorb predominantly the infrared radiation of the solar spectrum. It is used for windows and lantern lights of buildings and houses in the areas with hot climate to reduce transmission of the solar energy.

Wired glass has a wire mesh pressed in the glass melt while it is rolled. It is of higher safety and fire-resistance and is used for lantern lights, balcony windows and as partitions (Fig. 16).

Patterned glass is made from a clear or coloured glass melt processed by engraved rollers to produce a decorative surface. This type of glass is used in windows, partitions and doors where only translucent glass is required.

Tempered plate glass is made by a reheating and sudden cooling cycle. It has impact resistance and strength in tension several times higher than those of common glass, and is used for show windows, swinging and sliding doors, etc.

Uviol glass is made from the raw mixture with minimal admixtures of iron, titanium and chrome. It transmits 75% of ultraviolet radiation, i.e. far more than common glass and is, therefore, used for greenhouses, hospitals and establishments for children.

4.2. Glass Units

Many types of glass units are produced, such as glass block, multiple glass units, door glass and facing glass, etc.

Glass blocks (Fig. 17) are made in two halves sealed together to enclose an air space for thermal and noise insulation.

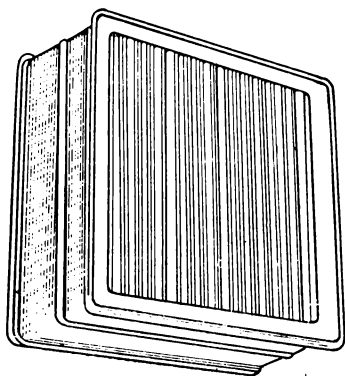


Fig. 17. Glass block

The face surface of glass block is patterned to make it light-diffusing.

Glass blocks come in size $194 \times 194 \times 98$ mm for glass masonry walls and in size $194 \times 194 \times 60$ mm for interior partitions. They transmit at least 65% of visible radiation and diffuse about 25%. Glass blocks are produced in both functional and decorative types.

Multiple glass units consist of two flat pieces of glass glued together so as to leave an enclosed air space between them. They are made of common window glass, strengthened glass, and heat-absorbing glass, and are used for windows of buildings.

Structural glass shapes come as box-, or T-shaped or ribbed units and are used for exterior purposes, skylights and curtain walls in industrial buildings (Fig. 18).

Door glass is made of heat-strengthened sheet glass. The edges of sheets are trimmed or slotted to receive metallic fittings. This type of doors is widely used in trading houses, public buildings and sports arenas.

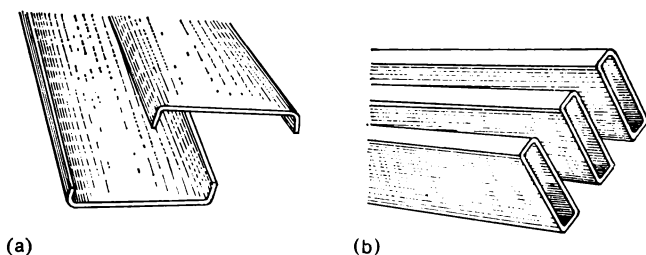


Fig. 18. Structural glass shapes
(a) channel; (b) box-shaped

Ceramic-coated glass is obtained from sheet glass by applying ceramic paint to one of the surfaces with subsequent thermal treatment. It is high in strength and in heat and frost resistance. This type of glass comes in sheets of various colours, 6-12 mm thick and 4 m² in area. Ceramic-coated glass is used as facing material for public and industrial buildings, for interior applications, and in the manufacture of multi-layer wall panels.

Facing glass tiles come as glazed in various colours or in mosaic pattern and are made of translucent coloured glass. Coloured tiles made of non-transparent glass have one face polished, and the other grooved. Glass tiles are used for interior facing purposes (where considerations of hygiene and ease of cleaning are important) and as exterior facing material.

Chapter V

Mineral Binding Materials

Mineral binding materials or binders are divided into air-drying and hydraulic ones. The *air-drying binders* are capable of hardening and preserving their strength only in the open air. They include air-drying lime, gypsum and magnesia binders, soluble glass.

Hydraulic binders can harden and preserve their strength not only in air but also in water. They include hydraulic lime, portland cement, puzzolana portland cement, slag portland cement, alumina cement, waterproof expanding and noncontracting cements and others. The hydraulic property of some binders can be strengthened by using natural or synthetic hydraulic admixtures.

5.1. Construction Lime

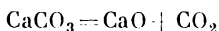
Construction lime is produced by burning calcium and magnesium carbonates. Depending on the hardening conditions, air-hardening and hydraulic limes are distinguished.

Air-drying lime provides for hardening of construction mixes and concretes in the dry-air conditions. It comes as quicklime and hydrated (slaked) lime. Air-drying (or common) lime is made by burning limestone that contains not more than 6% of clayey admixtures; the process results in a formation of lumps of white lime, known as lump quicklime.

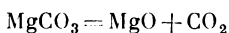
Depending on the further treatment of lump quicklime, the following kinds of common lime can be obtained: pulverized quicklime, resulting from powdering of lump lime; slaked hydrated lime (as fine powder) which results from slaking lime with a certain amount of water and consists essentially of Ca(OH)_2 ; lime putty (paste) produced by slaking lime with surplus amount of water; and lime milk resulting from treatment of lime by ample amount of water.

Production. Lime is produced from carbonate rocks (for example, limestone, chalk, dolomitized limestones) composed essentially of calcium carbonate, CaCO_3 , and impurities of magnesite, MgCO_3 , quartz and clays which affect the constructional value of lime.

The production process of lime includes: excavating raw material from pits, crushing and sorting it with subsequent burning in kilns. At 1 100-1 250°C calcium carbonate dissociates:



At the same temperature magnesium carbonate dissociates:



Carbonate dioxide, formed in this reaction, volatilizes and the resulting quicklime combines calcium oxide and magnesium oxide ($\text{CaO} + \text{MgO}$) which, being active com-

ponents of lime, define its binding property. Besides, lump quicklime will normally contain some amount of underburned and overburned material. The underburned material has almost no binding property and is actually a ballast. The overburned material results from fusing of calcium oxide with impurities (expanded clay, silica, iron oxide) under the action of high temperature. The overburned grains slake very slowly, therefore, their presence in lime is undesirable, since they may start slaking in the already hardened mortar, ready silicate units, etc.

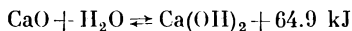
The lump quicklime obtained by burning consists of porous lumps having density 900-1 000 kg/m³ and is a semi-product which is further crushed or slaked to render it commercial.

The crushed lime is processed in ball mills and turned into quicklime powder (pulverized) lime which, in contrast to the slaked one, sets and hardens rapidly. Various additives can be added to lime as it is ground (slag, fly-ash, sand, pumice, limestone) to improve its quality and reduce cost.

Properties. Three grades of common fodder lime are distinguished, depending on the percentage of active CaO + MgO and the content of unslaked grains. Grade I calcium lime should contain at least 90% of active CaO + MgO, Grade II—80%, Grade III—70%; the content of unslaked grains should be respectively 7, 11 and 14%.

With respect to the slaking time, three types of construction lime are distinguished: quick (8 min), moderate (25 min) and slow (over 25 min). The higher the activity of lime, the more quickly it is slaked.

Slaking of lump lime with water is followed by the following reaction:



The reaction produces considerable quantity of heat and intensive steaming.

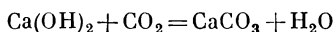
Depending on the amount of water used, hydrated lime, lime putty or slaked lime milk are produced.

Hydrated lime in the form of powder is obtained when the amount of water used for slaking is 60-70%, of which 32% takes part in the chemical reaction, the other part being evaporated. The volume of lime increases 2 or 3 times in the course of slaking. The resulting hydrated lime is a white powder consisting of fine particles of calcium hydroxide; its bulk density is 400-450 kg/m³ and density 500-700 kg/m³.

Lime putty results when the amount of water for slaking is 3-4 times that of lime. The volume of obtained putty is 2-3.5 times that of initial lime. The rate of volume increase is usually described by the volume of putty in litres which is obtained by slaking of 1 kg of lime.

Well-slaked lime which has increased in volume not less than 3 times is known as fat or rich lime and that of at least 2.5 times increase, as lean lime. The amount of putty produced depends on the content of calcium oxide in lime, quantity of foreign admixtures and the quality of burning. The lime putty presents itself a white plastic mass with a density of 1 400 kg/m³.

Hardening of lime. In construction, lime is usually used as mortar, i.e. as a mixture with sand. With a mortar prepared from slaked lime, several processes are taking place at a time. First, as surplus water evaporates from the mortar, fine particles of calcium hydroxide approach each other and form a tough crystalline skeleton that binds sand grains into a monolithic body. Simultaneously, calcium hydroxide of the mortar reacts with carbon dioxide from the atmosphere:



thus reverting back to calcium carbonate of high strength. However, the reaction is slow because of a firm film of calcium carbonate developing on the surface of mortar which hinders penetration of carbon dioxide into the mortar. This explains the slow hardening of lime mortars.

In the case of autoclaving lime mortar, when it is steamed at a pressure of 0.8 MPa and a temperature of about 175°C, an intensive interaction of lime, sand and water causes formation of insoluble and tough hydrosilicates of calcium that cement the sand and give a high strength to the material.

Hydraulic lime is produced by moderate burning of marlaceous limestones containing from 6 to 20% of clayey admixtures in shaft furnaces at temperatures from 900-1 150°C. At these temperatures calcium oxide combines with silicon oxide and alumina contained in clay, forming silicates and aluminates of calcium that enable the hardening of hydraulic lime in water.

When wetted, hydraulic lime will partially or fully slake and dissociate into powder, but given sufficient amount of water, it forms putty which, having started hardening in air, will do so in water, with the physico-chemical processes of air hardening combining with hydraulic ones.

Application of construction lime. Common lime is used to make lime-and-sand or compound mortars for brickwork and plastering, production of silicate units and slag-concrete blocks. Besides, common lime (powdered) and hydrated lime are used to produce lime-puzzolana and lime-slag cements, which in contrast to common lime have hydraulic properties.

Mortars and units made using common lime should not be used in humid premises and foundations, as they are not waterproof, and under freezing temperatures.

Powdered-quicklime mortars can be used under freezing temperatures, since during preparing and laying of mortar considerable amount of heat evolves, which makes the surplus water evaporate and the mortar harden quickly.

Hydraulic lime is used to make mortars for brickwork and plastering, and low-grade concretes that harden in both air and moist conditions.

Storage and handling. Quicklime is transported in tank cars or tipping trucks, in the latter case it should be protected from moisture. Hydrated lime and pulverized lime are transported in metallic containers or bitumen-impregnated bags; lime putty and milk are carried using trucks with special bodies.

Quicklime should not be kept at the jobsite, but supplied to it as required for making putty, which can be kept in troughs for longer time than lime itself. Hydrated lime can be stored in dry premises for a short time. Powdered lime should not be kept for more than a month as it is gradually slaked by the air moisture and eventually loses its binding property.

Hydraulic lime should be kept in dry premises and protected from moisture in transportation.

One must always remember about the harmful action of lime on human respiratory ducts and moist skin.

5.2. Gypsum Binders

Gypsum binders are air-hardening binding materials produced by thermal treatment and powdering of raw materials: gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, anhydrous gypsum CaSO_4 and some industrial wastes containing them.

Depending on the temperature of thermal treatment, the binders are divided into two groups: low-burned and high-burned. The low-burned binders are produced by thermal

treatment of gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ at temperatures from 150 to 180°C, which results essentially in formation of $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$ (plaster of Paris) characterized by fast hardening. The high-burned binders are obtained from gypsum or anhydrous gypsum at temperatures of 600-1 000°C, at which mainly CaSO_4 is formed, known for its slow hardening.

Gypsum plaster and high-strength plaster are referred to low-burned binders, while anhydrous cement and flooring plaster to high-burned ones. The former (construction gypsum) is most widely used in building to produce various units.

The most common technique of producing construction gypsum is as follows. Natural gypsum delivered to the manufacturing plant is crushed, dried, then ground to powder which is loaded into a boiling pan (a steel cylinder lined inside with brick). The pan contains four firetubes and a vertically-arranged mixer with blades. The furnace is arranged under the pan. Gases formed in the furnace heat the pan, as they rise along a circular gas duct which is also connected to the firetubes.

In the boiling pan, during $1\frac{1}{2}$ -2 hours gypsum is dehydrated, i.e., turned into $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$, then it is delivered to the withering bunker where it cools. Here, the process of dehydration of remained grains of gypsum goes on, owing to the residual heat. The advantage of this method is that the construction gypsum produced is uniform in quality and free from furnace ash.

Properties. Construction gypsum is a powder light-grey or white in colour with a bulk density between 800 and 1 100 kg/m³. It is a fast setting and fast hardening binder, its quality is described by the normal consistency of gypsum putty, setting time, fineness of grinding and strength in bending and compression.

The normal consistency of gypsum putty is described by the amount of water, expressed as percentage of mass at which a putty of a required workability is obtained. Usually this characteristic is determined using Suttard's viscometer.

Setting time is defined by Vick's apparatus. Setting of gypsum should begin no sooner than 4 min and end no sooner than 6 min but not later than 30 min after the tempering of gypsum has been started. Rapid setting is undesirable, therefore retarders are used.

According to the fineness of grinding, three grades of construction gypsum are distinguished using No. 02 sieve. The fineness of grinding is determined as percentage residue

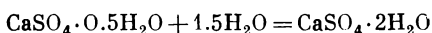
on the sieve, measured to the accuracy of 0.1 %. The residues should not exceed 15 % for grade I, 20 % for grade II and 30 % for grade III. The strength of gypsum increases with the fineness of grinding.

Strength of gypsum is determined on the samples with the size $40 \times 40 \times 160$ mm made from gypsum putty of normal consistency, giving them $1\frac{1}{2}$ hours for hardening. First the strength in bending is tested, then the strength in compression on half-size samples ($40 \times 40 \times 80$ mm).

The ultimate strength in compression of samples of the $1\frac{1}{2}$ -hour age should be not less than 5.5 MPa for gypsum grade I, 4.5 MPa for grade II and 3.5 MPa for grade III. The strength of gypsum increases further as water continues to evaporate.

Units made of gypsum, if moistured, sharply reduce in strength, giving way to plastic deformation. So, water resistance of gypsum is improved by admixtures of ground and granulated blast furnace slag or lime. Apart from this, gypsum units can be made waterproof by applying a coating of water-resistant compounds.

Hardening. The process of hardening of construction gypsum is, in fact, the process of hydration of $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$ (plaster of Paris), i.e., when it attracts water and transforms into gypsum:



The process of hardening may be split in three stages. The first stage begins when gypsum is mixed with water and $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$ is dissolved. Simultaneously, it attracts one and a half molecules of water and transforms into gypsum. Since gypsum is far less soluble than plaster of Paris, the solution formed earlier becomes supersaturated with respect to gypsum which precipitates from the solution.

At the second stage water reacts with $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$ and directly associates with the solid substance. This leads to the formation of gypsum in the form of fine crystals and colloidal gel.

At the third stage colloidal particles of gypsum recrystallize and form large crystals. The latter intergrow and form aggregations. It should be, however, noted that all these stages do not proceed in a strict sequence.

With further drying and crystallization of gypsum, it gains in hardness and strength. To accelerate the hardening process, units made of gypsum are subjected to drying at a

temperature not higher than 60-65°C, since at a higher temperature gypsum may dissociate, which is followed by a sharp decrease in its strength. When hardening, the volume of gypsum is increased by 1%, which ensures a good filling of moulds when units of gypsum are cast.

Application. Construction gypsum is used in production of wall boards and panels, gypsum plaster, ventilation ducts and other units used in buildings and structures where relative humidity of air is not higher than 65%. Gypsum is also used to make gypsum or lime-gypsum mortars, decorative and insulation units.

During transportation, construction gypsum should be protected from moisture and contamination. Gypsum should not be kept for a long time, as even in dry conditions it gradually loses its binding property.

5.3. Cement

Cements are the basic binding materials used in the construction industry. There are more than 30 types of cement available nowadays, but the most important ones are portland cement (66% of total production), slag portland cement (27%) and puzzolana cement (6%). Let us consider these basic types.

Portland cement is a hydraulic binder that hardens in water and in air, and is obtained by combined grinding of portland cement clinker and the required quantity of gypsum. Mineral admixtures can be fed to this mixture in the amount of 20% of cement (by weight).

Production. The following rocks are used as raw materials for portland cement: marls, limestones (chalk, shell rock, tufa) and clayey rocks. Limestone contributes to the cement the basic oxide CaO , clay brings in acid oxides SiO_2 , Al_2O_3 and Fe_2O_3 ; marl, a mixture of fine particles of lime and clay, introduces all oxides required for portland cement.

A rock, whose chemical composition would allow it to be processed into a satisfactory portland cement clinker, is rarely found; therefore, the raw feed is made up of two or more components. Normally the raw feed consists, on the average, of limestone (75%) and clay (25%). The proportion of the raw feed components is so chosen as to ensure, after burning, the following chemical composition of portland cement clinker: 64-67% CaO , 4-7% Al_2O_3 , 19-24% SiO_2 , 2-6% Fe_2O_3 .

The manufacture of portland cement includes the following processes, provided the raw material is already available: preparation of the raw feed, burning of the feed, grinding the clinker, together with the mineral additives, into a fine powder.

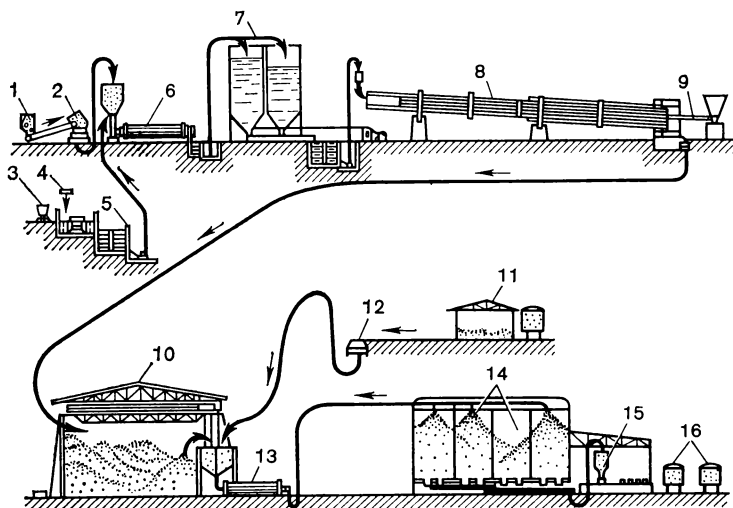


Fig. 19. Layout of a portland-cement manufacturing plant (the wet method)

1—limestone bin; 2—limestone crusher; 3—clay-charging car; 4—metering tank; 5—stirring basin; 6—raw-feed mill; 7—slurry basin; 8—rotary kiln; 9—fuel nozzle; 10—clinker store; 11—gypsum store; 12—gypsum crusher; 13—ball mill; 14—cement silos; 15—packing plant; 16—buggies for cement

Depending on the properties of the raw material and type of the cement kiln, the raw material is prepared for the kiln either dry or wet.

With the wet process (Fig. 19), the raw components are crushed, each separately, then mixed up and ground in the raw-feed mill. The resulting slurry (with water) is pumped into slurry basin 7, where it is analyzed and, if required, corrected.

The raw kiln feed is fed into rotating cement kiln 8, which is a cylinder 185-230 m long and 5-7 m in diameter, with an inside firebrick lining. The inclined kiln is rotated at 1-2 rpm by an electric motor. The raw kiln feed, charged into the kiln at the high end, tumbles slowly down to the discharge end meeting the flue gas coming up from the bur-

ner, where it forms as the fuel is burned. The fuel is fed through nozzle 9.

As the raw feed moves down the kiln it is progressively heated by the hot gases. When it is in the temperature zone of 300-600°C, it starts drying, forming a product in pellet form. In the zone of 500-750°C, the organic substances burn out and the clay component is dehydrated. Within the zone of 900-1 000°C, carbonates decompose to carbon dioxide and calcium oxide CaO. The latter undergoes a chemical reaction with silica, iron oxide and alumina. At 1 200-1 250°C, a solid-state chemical reaction becomes intensive enough and produces calcium silicates: dicalcium silicate $2\text{CaO} \cdot \text{SiO}_2$ (abbreviated C_2S), tricalcium aluminate $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ (abbreviated C_3A), and tetracalcium aluminoferrite $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ (abbreviated C_4AF).

At above 1 300°C, C_3A and C_4AF melt and form a liquid in which CaO and C_2S dissolve partially until the solution is saturated, and at about 1 450°C they react with each other to form tricalcium silicate $3\text{CaO} \cdot \text{SiO}_2$; abbreviated C_3S .

The product of the kiln is a pelletized grey-green slag called clinker. To cool down it to 80-100°C, it is conveyed to the cooler, wherefrom it is delivered to store 10. Here, the clinker is kept one or two weeks to allow for the amount of calcium oxide remaining uncombined to be slaked by moisture from air, which ensures uniformity in the volume change of cement as it hardens.

Finally, clinker is delivered to ball mills 13. As it is ground, about 3-5% gypsum is added to it to control the setting time of cement, and active mineral additives. The ready cement is kept in silos 14 for 10-14 days, then packed and despatched to the consumer.

With the dry process of portland cement manufacture, limestone and clay are first crushed and dried, then ground together. The resulting raw powder is processed into granules 20-40 mm in size, which are burned in the kiln into clinker. The clinker is ground together with gypsum and other additives.

Compositton. Portland cements are composed of four principal chemical compounds:

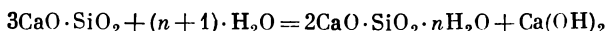
1. Tricalcium silicate, C_3S .
2. Dicalcium silicate, C_2S .
3. Tricalcium aluminate, C_3A .
4. Tetracalcium aluminoferrite, C_4AF .

The content of these compounds usually varies within certain limits: 40-65% C_3S ; 15-40% C_2S ; 3-15% C_3A and 10-20% C_4AF .

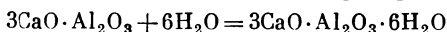
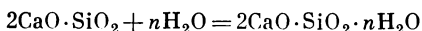
Each of these compounds has its specific physical properties which predetermine the certain properties of portland cement. For example, tricalcium silicate contributes to cement the high strength and the ability of rapid hardening; tricalcium aluminate ensures, together with the intensive gain in hardening at the one-day age, the active release of heat. These compounds are the most active constituents of cement.

Hardening process. When portland cement is mixed with water, a plastic and sticky slurry is formed which gradually thickens and hardens until it becomes stone-like. The process of portland-cement hardening may be arbitrarily divided into three stages: dissolution, formation of colloids, and crystallization.

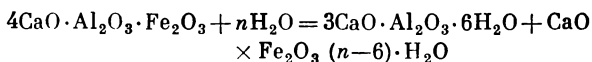
When cement is mixed with water, the principal chemical compounds of cement are dissolved until the solution is saturated, i.e. they no longer dissolve. But interaction of these compounds with water continues. Reactions in which water is taken up by the chemical compounds of cement are known as hydration and those in which these compounds are decomposed under the action of water, as reactions of hydrolysis. For example, hydrolysis of tricalcium silicate is followed by formation of new compounds—calcium hydrosilicate and calcium hydroxide (unbound lime):



Dicalcium silicate and tricalcium aluminate are only hydrated forming, respectively, calcium hydrosilicate and calcium hydroaluminate:



Tetracalcium aluminoferrite, when hydrolyzed, forms calcium hydroaluminate and calcium hydroferrite in the reaction:



These hydrated compounds are of poor solubility and rapidly saturate the solution.

The colloidal stage is characterized by the solid-state hydration of the principal compounds in the saturated solu-

tion, i.e. by taking up of water by the solid-phase binder without its prehydration. The reaction results in new hydrated compounds in the colloidal form. At this stage the slurry loses its plasticity, in other words, it is setting.

At the third stage, calcium hydroxide and tricalcium hydroaluminate, very unstable in colloidal state, gradually rise to a more stable, crystalline state. Simultaneously, the slow-crystallizing calcium hydrosilicate gel becomes dense. The formed crystals of calcium hydroxide and tricalcium hydroaluminate grow together and penetrate the colloidal mass composed essentially of calcium hydrosilicate, thus producing a tough crystalline aggregation. This is followed by hardening of cement.

Cement rapidly gains in strength over first 7 days, then the strength gain proceeds slower until the age of 28 days, after which it is relatively slow, but may continue over several years.

In the humid and warm surroundings, cement will gain in strength continually, but in dry conditions the process of hardening may stop, consequently, the gain in strength.

The hardening process may be accelerated by increasing the surrounding temperature and introducing accelerators, for example, calcium chloride, sodium chloride.

Properties. The basic properties of portland cement are density, fineness of grinding, normal consistency, setting time, uniformity in volume change, strength in bending and compression.

Density of portland cement is between 3 050-3 150 kg/m³.

The fineness of grinding of cement is determined by a No. 008 sieve. The retained material should not exceed 15% by weight of the sieved sample.

Normal consistency of cement slurry is determined by the amount of water (%) required to obtain the specified workability. It is measured with Vick's apparatus by the depth of immersion of a metal rod into the slurry. The normal consistency of portland cement is taken as 22-26 %.

Setting time is determined by Vick's apparatus and is judged by the depth of needle penetration into cement. The setting should start not earlier than 45 min and end not later than 10 hours since preparation of slurry.

Uniformity of volume change of cement is defined as follows. Flat round samples of slurry are boiled and steamed. The quality of cement is evaluated by the extent of cracking or deformation. The presence of unstable CaO and MgO

in cement may be a cause of nonuniform change of volume as they are slaked with an increase in volume in the already hardened cement.

Strength of portland cement is described by its grade which is established according to the ultimate strength.

Application, transportation and storage. Portland cement is used to manufacture monolithic concrete and reinforced concrete constructions that function on the ground, in the underground and underwater conditions, and in the conditions of alternating action of water and freezing temperatures. Portland cement grade 400 is used to prepare mortar for foundations and walls of prefabricated buildings. Portland cement should not be used in structures that undergo the action of sea-water, mineralized, or even fresh water which flows or is under pressure head.

Cements are transported by railway using special cars or in ordinary cars, also by motor transport. Cement is delivered either in bulk or packed in bags.

Cements that come in bulk are stored in silos or bunker-type stores each grade and batch separately. Cement delivered in bags is stored in damp-proof premises.

Each batch of cement delivered should be marked at once with the time of delivery, type and grade of cement, and the quantity. If required, quality-control samples are taken.

During transportation and storage cement should be protected from moisture and contamination.

It should also be noted that in long-time storage cement can be densified into lumps due to moisture taken up from the surrounding air.

Categories of cement. Apart from the ordinary, there are several categories of cement (high-early-strength, plasticized, hydrophobic, sulphate-resistant, sand, etc.). Each type of cement has its specific properties which decide its application.

High-early-strength portland cement has a high content of rapid hardening principal compounds: 55-60 % C_3S and 8-10% C_3A , and extrafineness of grinding. The content of mineral additives in high-early-strength portland cement is limited to 10%, therefore its gain in strength over the age of three days is intensive. This type of cement is used for structures of monolithic concrete where forms must be removed as soon as possible, also when high strength is needed very quickly in cement.

Plasticized portland cement is made by grinding portland-cement clinker together with plasticizing additives. More

often concentrates of sulfate-yeast mix in amounts of 0.25 % of the cement mass are used as such an additive. Plasticized portland cement, as compared with ordinary portland cement, gives a higher plasticity to mortars and concretes.

Plasticized portland cement, due to improved workability of concrete mortars and their reduced water requirements, makes it possible to decrease the consumption of cement by 5-8 %, or due to less water added, to increase the strength, water tightness and frost resistance of concretes. It is advisable to use this cement for preparation of concretes to be applied in road, aerodrome and hydraulic engineering construction where structures are usually subject to regular freezing and thawing or moistening and drying.

Hydrophobic portland cement is produced by combined grinding of portland-cement clinker and a hydrophobic additive which is taken in amounts of 0.1-0.3 % of the cement. Surface-active organic substances, such as naphthenate soap, acidol, oleic acid, organosilicon liquids, are used as hydrophobic (water-repelling) additives. These substances form on the cement grains very fine water-repelling films which protect the grains against moisture. Therefore, this cement, even after a prolonged storage, preserves looseness and activity. During mixing of mixes the hydrophobic films are easily removed and the cement well sets and hardens.

Hydrophobic portland cement features the ability to increase the mobility of concrete mixes which, in turn, improves water resistance, water proofness and frost resistance of concretes.

Sulphate-resistant portland cement is made on the basis of portland-cement clinker of the following composition: about 50 % tricalcium silicate C_3S , not more than 5 % tricalcium aluminate, and the total of tricalcium aluminate and tetracalcium aluminoferrite $C_3A + C_4AF$ should be no more than 22 %. This is the grade 400 cement. If a mineral additive (for example, granulated furnace slag in amounts of 10 to 20 %) is added to the cement clinker of the above composition, sulphate-resistant portland cement with mineral additives grade 400 or 500 will be obtained. These types of cement feature a higher sulphate and water resistance, reduced heat release during setting and hardening, and a slower intensity of hardening at the beginning. The other properties of these cements are like those of ordinary portland cement.

High-early-strength and sulphate-resistant portland cements are utilized for manufacturing concrete and reinforced

concrete elements of external zones of hydraulic engineering large-size works which are in conditions of repeated freezing and thawing in fresh or low-mineralized water.

Cements for mortars. A special cement is used for mortars in order to save cement clinker. It is made by combined grinding of cement clinker, gypsum, and mineral additives (active—granulated furnace slag, low-alkali dust of electric filters of clinker kilns—and inertial or their mixtures) or by a thorough mixing of these materials separately ground. Depending on the mineral additives used, the content of cement clinker may be reduced up to 30% (sometimes up to 20%) of the cement mass. The grade 150 cement is used for preparing mortars. Plasticizing additives (lime, clay) or surface-active substances are recommended to add to mortars.

Portland cements with active mineral admixtures. This group includes cements which are produced by a combined grinding of portland-cement clinker and an active mineral admixture or by a thorough mixing of these components after they have been ground.

As active mineral admixtures use is made of diatomite, tripoli, volcanic ashes, pumice, tufa, granulated furnace slag, ashes of brown coal, peat, oil shale, low-burnt clay, waste of ceramic production.

There are puzzolana portland cements and furnace-slag portland cements, according to the type of active mineral admixtures.

Puzzolana portland cement is manufactured by grinding of portland-cement clinker of a standard composition, active mineral admixtures, and gypsum.

Puzzolana portland cement may contain from 25 to 40% of active mineral admixtures, which is determined depending on the composition of clinker and the activity of mineral admixture. The cement has grades 300 and 400 of light colour; its density is from 2 700 to 2 900 kg/m³; bulk density of loose cement is from 850 to 1 100 kg/m³ and in compacted state from 1 200 to 1 600 kg/m³. Standard thickness of puzzolana portland cement is from 25 to 36% (ordinary portland cement—22 to 26%).

Puzzolana portland cement features a slow increase in strength at the beginning of hardening, as compared with portland cement made from the same clinker. At a temperature below 10°C its hardening sharply falls and even ceases at all. At elevated temperatures, on the other hand, it

hardens more intensively than portland cement. Therefore, concrete products made with this cement should be subject to hydrothermal treatment in steam chambers. In hardening, this cement releases less heat than portland cement.

Concretes and mortars made with the use of puzzolana portland cement are more stable to the action of fresh and flowing water, however they have a lower frost resistance as compared with concretes and mortars on ordinary portland cement.

It should be kept in mind that in dry conditions the hardening of concrete made with this cement almost ceases, therefore during the first two weeks the concrete must be regularly moistened and protected against dehydration.

Portland-slag cement is obtained by combined fine grinding of portland-cement clinker and granulated furnace slag with some amount of gypsum being added. The same raw materials can be ground separately and then mixed. Portland-slag cement should contain granulated furnace slag in amounts not less than 21 % and not more than 60 % of the cement mass.

Grades 300, 400 and 500 of portland-slag cement are available. It is grey with a blue hue and contains metal particles which can be felt by magnet. Its density is from 2 800 to 3 000 kg/m³, bulk density from 1 000 to 1 300 kg/m³ when loose and from 1 400 to 1 800 kg/m³ when compacted.

As compared with portland cement, portland-slag cement releases less heat during hydration, concrete made of it has a higher water and sulphate resistance, but, as a rule, a lower frost resistance; the increase of strength at the beginning of hardening is slower. The growth in strength accelerates later on and in 2-3 months it is stronger than portland cement of the same grade. Portland-slag cement has an accelerated hardening at an elevated temperature and sufficient moisture. Concretes with this cement, when subject to hydrothermal treatment at a temperature of 80-90°C, become stronger than concretes with portland cement of the same grade hardened in the same conditions.

Portland-slag cements are utilized for manufacturing prefabricated reinforced concrete structures, as well as for preparing masonry and plastering mixes.

It is not recommended to use portland-slag cement for manufacturing reinforced concrete structures which will be in the condition of alternating freezing and thawing or moistening and drying.

¶ A new variety of portland-slag cement is sulphate-resistant portland-slag cement which is made of portland cement clinker of a standard composition, furnace slag, and gypsum. The grades of this cement are 300 and 400. This cement is used for manufacturing concrete and reinforced concrete structures which should be stable in sulphate-containing media.

5.4. Special-Purpose Cements

These cements differ very much from cements made on the basis of portland-cement clinker. This group of hydraulic cements includes alumina, expanding, and noncontracting cements and also puzzolana gypsum-cement binder. In addition, water glass, acid-proof cement and magnesia cements belong to this group, too.

Alumina cement is a high-early-strength hydraulic binding agent which is produced by fine grinding of burnt to caking or to melting mix rich in alumina. As raw materials use is made of limestone or lime and rocks having a high content of alumina Al_2O_3 , bauxite for example.

The composition of alumina cement is characteristic for a high content of low-base calcium aluminates, single-calcium aluminate $\text{CaO} \cdot \text{Al}_2\text{O}_3$ being the principal one.

This cement is a fine powder, grey-green, brown or black in colour. Its density is 3 to 3.2 g/cm³; bulk density when loose is from 1 000 to 1 300 kg/m³ and when compacted from 1 600 to 1 800 kg/m³; standard thickness is usually from 23 to 28%. Fineness of grinding is somewhat higher than that of portland cement. Its setting starts not earlier than in 30 min and stops not later than 12 h from the time of mixing the cement with water.

The hardening process of alumina cement is attended with a considerable heat release, which restricts its application in large-size concrete structures, however it is very useful in construction work in winter.

Alumina cement is available in three grades: 400, 500 and 600. It intensively gains strength at the beginning of hardening. In 24 hours, for example, it has 80-90% of standard strength.

Concretes made with alumina cement are water tight, stable in conditions of fresh and sulphate waters, and also frost resistant. They readily harden in humid environment at 15-20°C. The strength of concrete is considerably

reduced at temperatures above 25°C. Therefore these concretes are not to be steamed or heated. Alumina cement must not be mixed with portland cement, otherwise its strength will be decreased.

Alumina cement is used in urgent repair and emergency jobs, in production of concrete and reinforced concrete structures subject to action of heavily mineralized waters, for concreting in winter, for manufacturing heat resistant concretes.

Expanding portland cement is produced by a combined fine grinding of 58-63% portland-cement clinker, 5-7% alumina slag, 7-10% dehydrate gypsum and 23-28% granulated furnace slag. The portland-cement clinker should contain at least 53% C_3S . The setting time is the same as for portland cement.

Linear expansion of the cement after 28 days is at least 0.05%, if it hardens in air and is wetted during first three days. When it hardens in water, linear expansion after 28 days comes to at least 0.2 and not more than 2%.

Expanding portland cement is used for preparing noncontracting and expanding waterproof concretes and mortars for monolithic and built-up concrete and reinforced concrete structures and for filling seams between structural elements.

Waterproof expanding cement is a rapid-setting and high-early-strength hydraulic binder, which is obtained by combined grinding and mixing of milled alumina cement, gypsum and calcium hydroaluminate. It begins setting in 4 min and stops setting not later than in 10 min from mixing. Linear expansion of specimens from this cement after 24 h hardening should be within 0.3-1%.

Waterproof expanding cement is employed for caulking and hydraulic insulation of seams in tubbings, faucet joints, for making hydro-insulating roofings, for filling butts and cracks in reinforced concrete structures. It is not to be used for structures which operate at a temperature above 80°C.

Waterproof noncontracting cement is a rapid-setting and high-early-strength hydraulic binder which is manufactured by thorough mixing of alumina cement, semiwater gypsum and slaked lime. The beginning of setting is in one minute and the end, not later than in 5 min from the time of mixing. Linear expansion of specimens made of cement grout after 24-h hardening in water should be within 0.01-0.1%.

This cement is used to build hydro-insulating gunned concrete enclosures in concrete and reinforced concrete

underground structures in conditions of elevated humidity (tunnels, foundations).

Gypsum-alumina expanding cement is a high-early-strength hydraulic binder produced by combined fine grinding of high-alumina slags and natural dehydrate gypsum.

Gypsum-alumina cement expands only when hardening in water, it is noncontracting when hardens in air. The beginning of setting should be at least in 20 min and the end, not later than in 4 h from the time of mixing. Linear expansion of specimens made from cement grout of standard thickness and placed in water one hour after they are made should be in 24 h at least 0.15%, in 28 days at least 0.3% and not more than 1%.

Gypsum-alumina cement is used for preparing noncontracting and expanding waterproof mortars and concretes, for caulking joints and butts, for strengthening structures and making them monolithic.

Self-stressing cement mixed with water first hardens and gains strength then expands like a solid and stresses reinforced concrete. This cement is used for making pressure pipes, monolithic and sectional water reservoirs, for cement-concrete coverings of aerodromes and in underground structures.

Puzzolana gypsum-cement binder is obtained by mixing 50-75% of building or high-strength gypsum, 15-25% of portland cement and 10-26% of puzzolana (hydraulic) admixture. Instead of portland cement it is advisable to add puzzolana portland cement with a required amount of active additives, as well as portland furnace-slag cement.

This binder is quick to harden and has a higher waterproofness. The strength of concretes made with the use of this binder is from 15 to 30 MPa, they attain 30-40% of standard strength as soon as 2-3 h after they have been prepared. To speed up the hardening of these concretes they are subject to steam curing at 70-80°C. In this case the concrete strength reaches 70-90% of final strength in 5-8 h. The softening coefficient of concretes is from 0.6 to 0.8, frost resistance from 25 to 50 cycles.

Puzzolana gypsum-cement binder finds application in manufacturing floor panels, sanitary cabins, air ducts and the like.

Water glass is an air-drying binding agent obtained by melting in glass-making furnaces of clean quartz sand with soda Na_2CO_3 or potassium carbonate K_2CO_3 with subsequent dissolution with steam to make a viscous mix. Soda water

glass is used for heat-resistant concretes and mortars, fire-protection coatings, and potassium water glass for preparing silicate paints, acid-proof mortars and concretes.

Acid-proof cement is an air-drying binder prepared by combined fine grinding of quartz sand and fluosilicate sodium or mixture of these materials, which when mixed with water glass produces an acid-proof silicate stone. This cement is not waterproof but is highly resistant to a number of mineral and organic acids.

Magnesia cement can be of two types: caustic magnesite and caustic dolomite.

Caustic magnesite is produced by burning magnesite MgCO_3 with subsequent grinding it into a fine powder, and caustic dolomite, by burning natural dolomite $\text{CaCO}_3 \cdot \text{MgCO}_3$ with subsequent grinding.

Magnesia cements give a good bond with sawdust, chip, reed and other organic aggregates which are not then subject to decay. These cements are used for making fibreboards and warm and wear resistant xylolite floors.

Chapter VI

Aggregates for Mortars and Concretes

Mortars and concretes are prepared by mixing several components, namely, binder, water, and aggregate. Aggregate constitutes 70-85% of the mix, forms a stone skeleton in the mortar and concrete, while the binder mixed with water wraps the aggregate grains and acts as a lubricant which gives fluidity to the mix. Proper selection of composition and the amount of aggregate decreases the consumption of binder and reduces the shrinkage of mortar and concrete.

According to the grain size, aggregates may be fine (sand) and coarse (gravel and crushed stone).

6.1. Sand

Natural and sometimes artificial sands are used as fine aggregates in preparing mortars and heavy-weight concrete.

The chemical composition of sand depends on the rock it is formed from. Often quartz sands with admixtures of feldspar and mica are found; sometimes limestone, shelly and dolomite sands occur.

Natural sands according to their occurrence conditions are divided into river (fluvial), sea (beach), and rock (ravine) sands. The grains of river and sea sands are round in shape; rock sands have angular grains, which provides for better bonding with cement stone. Rock sands, however, contain more harmful impurities.

Artificial sands are produced by crushing hard and solid rocks and furnace slag. They have angular rough-textured shapes; in contrast to natural sands they do not contain harmful impurities. Crushed sands are costly, therefore they are used only to enrich fine natural sand in production of high-strength concretes.

For mortars and heavy-weight concrete, sand is selected with regard to its properties and cost.

The quality of sand utilized in preparing a mortar or heavy concrete is basically determined by the grain composition and the content of harmful impurities. The grain composition of sand is characterized also by its fineness modulus. The grain composition of sand is essential for production of a given grade of mortar or concrete with a minimum consumption of cement.

According to grain composition, natural sands can be coarse, medium, fine, and very fine (Table 4).

Table 4

Characteristics of Sands

| Sand | Residue on sieve No. 063, % by mass | Fineness modulus, M_f |
|-----------|--|----------------------------|
| Coarse | Over 45 | Over 2.5 |
| Medium | From 35 to 45 | 2.5-2 |
| Fine | From 10 to 30 | 2-1.5 |
| Very fine | Up to 10 | 1.5-1.0 |

Coarse and medium sands (fineness modulus 2-3.25) are generally used for preparing heavy-weight concrete, the use of fine and very fine sands must be properly substantiated.

Sand of a grain size not over 5 mm, fineness modulus no less than 1 and residue on sieve No. 014 not over 20% by mass is suitable for mortars.

The bulk density of sand depends on its hollowness, moisture content and density. Since the sand density varies slightly (from 2 550 to 2 650 kg/m³), the volume of voids and hence the quality of sand grain composition can be assessed by its bulk density. The higher the bulk density, the better the sand grain composition. Usually the bulk density of loose dry quartz sand is 1 600-1 700 kg/m³.

At a moisture content of 5 to 7% the bulk density of quartz sand is minimum. This should be taken into account in volume proportioning of sand, and also when it is excavated.

The quality of sand for making concrete is also determined by the content of harmful impurities (clay and dust particles, organic impurities, sulphur and sulphuric acid compounds and mica), the amount of which should not exceed the permissible limits.

Clay and dust particles add to the total surface of the aggregate in which case the concrete mix takes more water and, as a result, the strength of concrete decreases. Besides, clay impurities envelope the sand grains and this deteriorates the bonding between them and the cement stone and reduces the strength of the mortar and the concrete. The amount of clay and dust (silty) particles, determined by elutriation, should not exceed 5% in sand used for mortars and 3% for concrete by mass.

Sand containing dust, clay and other impurities exceeding the permissible values is used for preparing mortars and concretes after it is rinsed in special sand washers.

Organic impurities, such as vegetation remains, humus, impair the strength of cement stone in concrete and may cause its failure. The degree of sand contamination with organic impurities is determined by the calorimetric method which involves treatment of a sand sample with a 3% solution of caustic soda. The sand is considered to be suitable for making concrete, if after treatment its mix is not darker than the standard.

Sand is also considered to suit for preparing a mortar, if the strength of mortar samples is not lower than the strength of samples made from the same sand after washing it with lime milk and then with water.

6.2. Gravel and Crushed Stone

These are utilized as coarse aggregates in preparing heavy-weight concrete.

Gravel may be rock, river, and sea one. Rock gravel has a rough surface, it usually contains sand, clay, dust and organic substances. Sea and river gravels are purer than rock gravel, but with a smooth surface which impairs its adhesion with a cement-sand mix. For better adhesion, it should be crushed.

Crushed stone is a loose material produced by crushing various hard rocks, brickbats, slags, etc. The obtained grains (5 to 70 mm in size) are screened into fractions.

Crushed stone differs from gravel by angular shape and rough surfaces of grains, therefore it bonds well with cement-sand mix. The content of harmful organic impurities in crushed stone is negligible.

The quality of a coarse aggregate is estimated in the laboratory by testing its sample and is characterized by the coarseness and the shape of grains, the content of harmful impurities, strength and frost resistance.

Gravel and crushed stone, according to the coarseness of grains, are divided into the following fractions: 5 to 10, 10 to 20, 20 to 40 and 40 to 70mm. Each fraction of gravel or crushed stone should contain grains of all sizes—from the largest to the smallest for the given fraction.

In preparing concrete, it is more economical to use large-size gravel or crushed stone, since in this case the consumption of cement is reduced due to a smaller total surface of grains. The size of aggregate grains, however, is limited by the dimensions of structures being concreted and the space between the reinforcement bars. The greatest size of grains of a coarse aggregate should not be more than one third of the least size of the structure being concreted, or not more than three fourths of the least distance between the reinforcement bars. In making concrete slabs, it is permissible to apply up to 50% of coarse grains, the largest in size equal to half the slab thickness. For thin-wall heavily reinforced structures, use is made of aggregates up to 20 mm in size, and for heavier structures, up to 40 and even up to 70 mm. The content of grains larger than the permissible maximum size may not be over 5% (of the gravel or crushed stone mass).

For preparing concrete, it is recommended to use round-shaped gravel or cubical-shaped crushed stone.

The amount of dust, silt and clay particles in a coarse aggregate may be from 1 to 3%, depending on the concrete grade and kind of aggregate. Besides, the presence of clay in the form of film coating the aggregate grains is not admissible, and the amount of clay in lumps should not exceed 0.25%.

Organic impurities lower the quality of a coarse aggregate, therefore their content is determined, as in the case of sand, by the calorimetric method.

The strength of grains of a coarse aggregate has a substantial effect on the strength of concrete made of it. The strength of crushed stone, in turn, depends on the strength of source rock. For heavy concretes, use is made of crushed stone produced from rocks having the strength 1.5-2 times higher than that of the preset grade of concrete.

The fitness of gravel and crushed stone for concretes of various grades is preliminary established by the crushability index, when it is crushed in a steel cylinder. Finally, the fitness of gravel or crushed stone for a concrete of a required grade is established from the test results of the concrete with the given aggregate.

Frost resistance of gravel and crushed stone is determined by alternately freezing and thawing them when saturated with water. By frost resistance, gravel and crushed stone are assigned the following grades: 15, 25, 50, 100, 150, 200, and 300.

6.3. Quarrying, Transportation and Storage

Natural aggregates used for mortars and concrete mixes, before application, are, as a rule, prepared, i.e. freed of harmful impurities, crushed, and screened. Aggregates are commonly prepared in quarries.

River and sea sands are found in pure form, however rock sand sometimes should be rinsed in special machines (sand washers) to remove harmful impurities and small particles.

Gravel is obtained by working sand and gravel deposits primarily along the banks of rivers and natural reservoirs by the hydraulic method and with excavators. The mix of sand and gravel is separated in water with vibratory and drum screens into required fractions and washed at the same time to remove dust, clay and other particles.

Crushed stone is produced at aggregate preparation plants located nearby the quarries. It is sorted in flat vibratory screens.

Aggregates are stored in the open or in stores, equipped with trestles, underground galleries, in stacks separately by types and fractions. During transportation, unloading and storage, care must be taken to prevent mixing of different types of aggregates and contamination with foreign admixtures. In winter, measures should be taken to loosen the frozen aggregates and to heat them.

Chapter VII

Mortars

7.1. Types of Mortars

Mortar is an artificial stone material obtained as a result of setting of a properly chosen mix of a binding material, water, fine aggregate (sand) and in some cases various admixtures (mineral, surface-active, chemical, etc). The mixture of these materials before setting is called a *mortar mix*.

By density, mortars can be heavy-weight ($1\,500\text{ kg/m}^3$ and more) which are made with the use of heavy quartz or other sands, and light-weight (less than $1\,500\text{ kg/m}^3$) which contain light porous sands such as pumice stone, tuff, slags, expanded clay aggregate and other light-weight fine aggregates.

By the type of binder, used mortars are divided into cement (on portland cement or its varieties), lime (on air-slaked or hydraulic lime), gypsum (on gypsum binders), combined (on cement-lime, cement-clay, cement-gypsum binder). Mortars made with one binder are called common mortars and with several binders, complex mortars. The binders are chosen depending on the purpose of a mortar, requirements imposed on it, temperature and moisture conditions of setting, and service conditions of the building or structure.

Mortars according to *job specifications* are divided into mason's mortars used for brickwork and erection (bedding)

of blocks and panels, finishing used for plastering and application of surface courses on wall blocks and panels, special-purpose with particular properties (for example, water proofing, acoustic, X-ray protection).

Portland cements, portland-pozzolana cements, portland blast-furnace slag cements, special low-grade cements (grade 200, for instance), and also lime and gypsum are used for masonry binders.

With the aim of economy of hydraulic binders and improving the properties of mortars, wide use is made of combined binders consisting of cement and lime, cement and clay.

Lime is used in mortars as lime paste or lime milk.

Water used for mixing mortars should be free of impurities that may affect the setting of binder. Generally, tap water is utilized for the purpose.

As a fine aggregate for heavy-weight mortars, use is made of quartz and field-spar natural sands, as well as sands produced by crushing solid rocks; for light-weight mortars, pumice, tuff, expanded clay aggregate, perlite and blast-furnace sands are used.

Mineral or organic plasticizers are added to mortars to improve their placeability. Cement and lime mortars are plasticized with clay in the form of clay milk or fine powder. Besides, fine hydraulic additions (tripoli, lava ash, etc.), industrial fly ashes, stone-working rejects in the form of slurry are also added to mortars.

Nigre, sulfite-alkohol distillary grains, naphthenate soap are used as organic plasticizers.

The mortars intended for use in winter are made with early-strength admixtures or setting accelerators and the additions which lower the freezing temperature of water (for example, calcium chloride, sodium chloride, potash, sodium nitrate).

The composition of mortars is designated by two or three numbers. For instance, the composition of a common cement mortar 1 : 4 means that in the given mortar four unit volumes of filler—sand—are accounted for a unit volume of cement. The composition of compound mortars is designated by three numbers. For example, a cement-lime mortar of 1 : 0.5 : 5 composition contains one part of cement, 0.5 part of lime and five parts of aggregate.

The composition of a building mortar is selected in laboratories where, proceeding from the preset mortar grade, cement activity and degree of mobility of the mortar mix

first the approximate composition of the mortar is calculated, then the water consumption is defined by trial batches. The determined relationship between the mortar components (cement, plasticizing mineral addition, water and sand) should ensure a mortar with a preset mobility and the required strength at a given time.

7.2. Properties of Mixes and Mortars

The properties of fresh mixes and mortars and their properties in the set state determine their field of application.

Mixes. Mobility, water-holding capacity and segregation are the main properties of a mix.

Mobility of a mix is its ability to spread easily over the surface of stone with a thin layer and fill all irregularities. The degree of mobility of a mix is determined with a standard cone (Fig. 20a) which is 300 g in mass, 15 cm high, with the apex angle of 30°. The cone is placed in a mix with its apex: the more the submersion depth, the greater the mobility of the mix. The mobility is measured in centimetres of the cone submersion. At building sites, the cone of the same mass without upright and with a shorter rod (Fig. 20b) may be used.

The mobility of a mix depends on the amount of water present in it, the composition of mix and the properties of raw materials. Plasticizing mineral and surface-active substances are added to improve the mobility of mixes. Plasticizing additions make it possible to attain the desired mobility with less amounts of water and cement, i.e. to produce mixes with a higher density and strength and to save cement.

The working mobility of a mix in summer and winter is taken according to its purpose and the type of wall material (in cm):

| | |
|---|-------|
| Common brickwork: | |
| solid bricks and also concrete and natural stones of light rock | 9-13 |
| perforated bricks or structural clay tile | 7-8 |
| Rubble masonry | 4-6 |
| Filling voids in rubble masonry | 13-15 |
| Vibration rubble masonry | 1-3 |

For masonry of dry and porous rock materials, use is made of mixes with a higher mobility, and for masonry of moist and dense materials, those with a lower mobility.

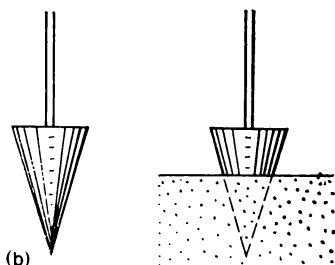
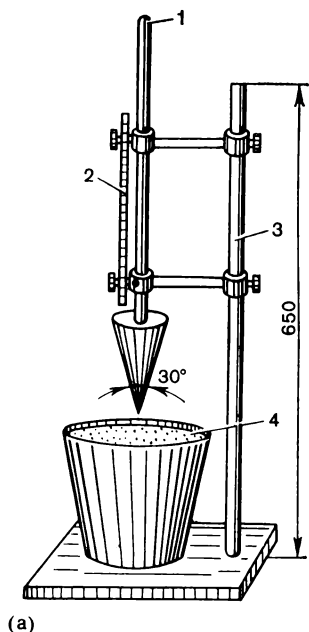


Fig. 20. Cones for determining the mobility of mortars

(a) standard; (b) with a short rod; 1—sliding rod with a cone; 2—graduated rule; 3—upright; 4—vessel with mortar

Water-holding capacity is the property of a mix to hold water when placed on a porous surface and also not to segregate during transportation. Partial suction of water out of a mix having a good water-holding capacity compacts the mix in masonry and improves its strength. Water-holding capacity depends on the relation of the components in the mix; it is higher when more cement is used, when part of cement is replaced with lime, when high-dispersive materials (ash, clay, etc.) and some surface-active substances are added.

Segregation consists in that the homogeneous mix, when transported by dump trucks or pipelines, is separated into sand and binder which descend while water goes up. In pipelines such a mix forms blockages, elimination of which takes much time.

Segregation may be prevented by proper composition of the mix in which the binder fills all voids between aggregate grains and uniformly envelops each particle. Plasticizing additions (clay and lime) improve the water-holding capacity of mixes and reduce their segregation.

Mortars. Strength and frost resistance are the principal properties of mortars.

Strength of a set mortar depends on the brand of cement, water to cement ratio, duration and conditions of setting (temperature and moisture of environment). The strength of set mortars placed on a porous base, which intensively

sucks water, is considerably higher than that of mortars placed on a dense base.

The strength of a mortar is determined by its brand which is established by the ultimate strength in compression (kgf/cm^2) of specimens in the form of cubes $70.7 \times 70.7 \times 70.7$ mm or beams $40 \times 40 \times 160$ mm in size made of a mortar, after 28-day setting at a temperature of $15\text{--}25^\circ\text{C}$. Mortars are assigned the following brands: 4, 10, 25, 50, 75, 100, and 200.

In moist conditions, mortars are capable of setting and gaining strength for a long time. For example, the mean strength of a mortar after 7 days is 40-50% of working strength, after 14 days—60-75%, after 60 days—120% and after 90 days—130%. If cement and combined mortars set at a temperature other than 15°C , then the value of relative strength is found from special tables.

Note that mortars made with portland-slag or portland-pozzolana cement are very slow in growing strong at a low positive temperature ($3\text{--}5^\circ\text{C}$).

Frost resistance of a set mortar is characterized by the following grades: 10, 15, 25, 35, 50, 100, 150, 200, and 300. The required grade is obtained by calculation and selection of the mortar composition. Frost resistance is determined by testing specimens in freezing chambers.

7.3. Mortars for Masonry and Erection Work

Strength, monolithic character and durability of masonry and fabricated buildings considerably depend on the mortar used. The brand, type and composition of mortars for various kinds of masonry and erection work are established taking into account the strength, nature of structures and conditions of their usage. Building mortars of brands 25, 50, 75 and 100 are mostly used now in civil and industrial engineering.

For masonry of exterior walls of buildings, primarily combined cement-lime and cement-clay mortars, brands from 25 to 50, depending on the type of material used and the required durability of structure, are applied.

The compositions of mortars for masonry with the use of various brands of cement are given in Table 5.

In erecting walls of concrete panels, the horizontal seams are filled with mortars not below brand 100 for panels made of heavy-weight concrete and not below 50 for panels made

Table 5

Compositions of Mortars for Masonry

| Cement brand | Batching by volume for mortar brands | | | |
|--------------|--------------------------------------|-------------|---------------|--------------|
| | 100 | 75 | 50 | 25 |
| | Cement-lime | | | |
| 400 | 1 : 0.3 : 4 | 1 : 0.5 : 5 | 1 : 1 : 8 | — |
| 300 | 1 : 0.2 : 3 | 1 : 0.3 : 4 | 1 : 0.7 : 6 | 1 : 1.7 : 12 |
| 200 | — | 1 : 0.2 : 3 | 1 : 0.4 : 4.5 | 1 : 1.2 : 9 |
| | Cement | | | |
| 400 | 1 : 4 | 1 : 5 | — | — |
| 300 | 1 : 3 | 1 : 4 | 1 : 6 | — |
| 200 | — | 1 : 3 | 1 : 4.5 | — |

of light-weight concrete; horizontal and vertical seams in walls made of large blocks and panels are pointed with mortar brand 50. For underground masonry and masonry below the hydraulic isolation layer, when the ground is saturated with water, cement mortars of brands 50 and 75 are used.

The composition of mortars is selected, as a rule, from suitable tables and the quality of the mortars obtained is tested in laboratories.

In selection of a composition of the mortars given in Table 5 it was assumed: cement brands 200 to 400 with a bulk density of 1 400 kg/m³, loose sand with a moisture content of 1-3%, lime paste of grade II with a density of 1 400 kg/m³.

At negative temperatures, walls of brick and other materials are built by the freezing method, i.e. heated mortar freezes under bricks. The brand of mortar by strength is assigned according to the design recommendations, taking into account the ambient temperature.

Mortars should be prepared in heated rooms with the use of hot water (not above 80°C) and heated sand (not above 60°C). To reduce the freezing temperature, sodium nitrate in the amount of 5 to 10% of water is added to the mortar.

At the workplace, the mortar is kept in heated boxes provided with covers, at air temperatures below -10°C the mortar should be heated with tubular electric heaters.

7.4. Special-Purpose Mortars

These are hydraulic insulating, injection, acoustic, and X-ray protection mortars.

Hydraulic insulating mortars, used for plastering surfaces of various vessels for liquid products, walls of basements, are made with portland cement, sulphate-resistant portland cement and water proofing expanding cement. Approximate composition of mortars for hydraulic insulating plaster is 1 : 2.5 or 1 : 3.5 (cement : sand by mass). To increase the water proofness of plasters, various compacting admixtures, such as sodium aluminate, emulsified asphalt, and latexes, are added to the mix.

Injection mortars, or filling grouts, are intended to fill channels in prestressed constructions for protection of reinforcement against corrosion. They may be as cement-sand mixes prepared with fine sand or as cement slurry. As a binder, use is made of portland cement brand 400 and higher, consumption of which should be from 1 100 to 1 400 kg per m³ of the cement-sand mix and from 1 300 to 1 600 kg per m³ of the cement slurry.

The brand of injection mortar should be not below 300. To reduce viscosity, it is advisable to introduce into the mix the surface-active substances (sulphite-alcohol distillary grains, or naphthenate soap) in amounts of not more than 0.2% of the cement mass.

Acoustic mortars are utilized for making sound-proofing plasters. Portland cement, portland-slag cement, lime gypsum are used as binders, and single-fraction sands 3-5 mm in size made of light-weight porous materials (for example, pumice, perlite, expanded clay aggregate) as aggregates. The amount of binder and the grain composition of aggregate in acoustic mortars must provide apparent porosity and a mortar density from 600 to 1 200 kg/m³.

X-ray protection mortars are used for plastering the walls and ceilings of X-ray rooms. They are made of portland cement or portland-slag cement and barite sand with grains not over 1.25 mm. The density of these mortars is usually 2 200 kg/m³ or less.

7.5. Preparation and Transportation of Mortars

Building mortars are prepared as mixes with a preassigned mobility, ready for use or in the form of dry mixes of various compositions (masonry, plastering) which are mixed, before application, with water and, in some cases, special admixtures are introduced. Mortars are usually prepared at the concrete-

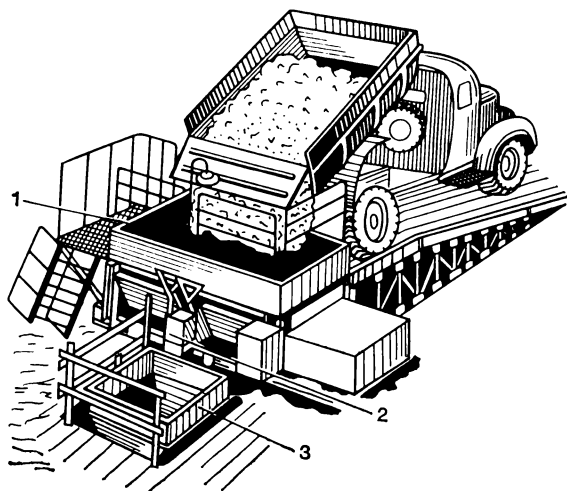


Fig. 21. Installation for unloading, mixing and discharging of mortar at a construction site

1—mixer; 2—gate to discharge mortar; 3—bin

mixing and mortar-mixing plants and only when the volume of work is small or a centralized production of mortar is far away they are prepared at site.

The process of making mortars consists in preparing raw materials, their batching and mixing. Raw materials should be free of harmful impurities. Sand should be screened, lime and clay slurry are made of a required consistency, organic plasticizers and chemical admixtures are dissolved in heated water in an amount required for the working concentration of mortars.

Mortars are prepared in 150, 375, 750 or 1 500 litres cyclic or continuous-action mixers. Heavy mortars are mixed for 1-2 min, light mortars, for 2-3 min, mortars with organic plasticizers, up to 4 min. Dry mixes are dissolved with

water in small capacity mortar mixers installed at the construction site.

Mortars are transported to the construction site in special tanks or dump trucks. When transported to a distance of over 10 km, the mortar, to avoid segregation, should be mixed again before application. At the construction site the mortar is unloaded into a bin (Fig. 21) where it is also mixed.

Each batch of mortar delivered to a construction site should be provided with a certificate in which the type, batch number, volume, date of production, brand, composition, mobility and water-holding capacity of the mortar are indicated.

Chapter VIII

Concretes

8.1. General Data and Classification

Concrete is an artificial stone obtained through the hardening of a properly selected, carefully mixed, and consolidated mixture of a binder (cement), water, aggregates, and (where necessary) special additives. Before this mixture begins to harden it is called a *concrete mix*.

The mineral binder and water are the active constituents of concrete. A new compound is formed through their chemical interaction in the form of an adhesive paste which envelopes the grains of the fine and coarse aggregates, and then, with time, hardens and binds them together, converting the concrete mix into a solid monolithic stone, concrete.

In order to prepare a concrete mix, either potable water or natural water free of detrimental impurities (e.g. sulphates, mineral or organic acids, fats, sugar) that would prevent normal setting and hardening of the concrete, is used.

The filler or aggregate (sand, crushed stone, or gravel) occupies 80 to 85 per cent of the concrete volume and forms its rigid skeleton, which prevents shrinkage or contraction. The structure of ordinary concrete is shown in Fig. 22.

Concrete and reinforced concrete components and structural members of various shape and size are widely used in industr-

ial, housing, public building, road construction, and other civil engineering work.

The main criteria for classifying concretes are density, type of binder used, coarseness of the aggregate, and the purpose of the concrete.

Concretes are divided according to density (kg/m^3) into the following types: extra heavy (more than 2 500), heavy (from 1 800 to 2 500), light-weight (from 500 to 1 800), and very light (less than 500).

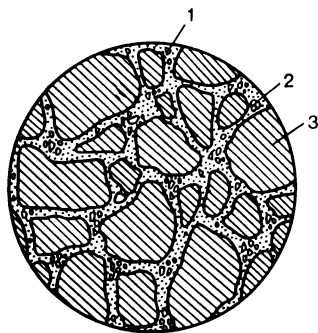


Fig. 22. Diagram of the structure of ordinary concrete
1—cement stone; 2—sand; 3—crushed rock

Extra heavy concrete is made from cement and natural or artificial aggregates (e.g. magnetite, heavy spar, blast-furnace scrap, steel chips). It is employed in nuclear installations as a defence against radioactive radiation.

Heavy (ordinary) concrete is made from natural, compact aggregates (sand, crushed stone, or gravel), and has quite a compact structure. It is used to make load-bearing reinforced concrete structural members.

To make *light-weight concretes*, natural and artificial porous aggregates are used (e.g. tuff, pumice, expanded clay aggregate, and slag pumice). Wall panels and blocks and other enclosing constructions are made from light-weight concretes.

Heat-insulating items are made from *very light concretes*, which are characterized by a high uniform porosity.

Depending on the type of binder used, concretes are classed as cement concrete (binders: portland cement and portland blast-furnace cement); autoclave-hardened lime concrete (binders: lime-sand, lime-slag, etc.); gypsum (gypsum binders); bituminous concrete, and polymer-concrete (organic binders).

Depending on the coarseness of the aggregate, concretes are divided into fine-grained (aggregate size of less than 10 mm) and coarse-grained (maximum grain size from 10 to 150 mm).

According to their use, concretes are divided into ordinary concrete (to make concrete and reinforced concrete load-

bearing structural members of buildings and structures—viz. foundation blocks, columns, beams and girders, and panels); hydraulic concrete (the erection of dams, building of locks, facing of canals); concrete for the walls of buildings and light structures; road concrete (for surfacing roads and aerodromes); and special concrete (e.g. acid-resistant, heat-resistant, decorative, and extra heavy for biological protection).

Bricklayers and masons usually have to deal with heavy concretes in their work, we shall therefore limit ourselves to a consideration of them.

8.2. Properties of a Concrete Mix and Concrete

A **concrete mix** is a rationally selected and carefully mixed mixture of a binder, aggregate, water, and (where necessary) an additive (plasticizer and accelerator) before it is placed in a form and begins to set. The properties of a concrete mix

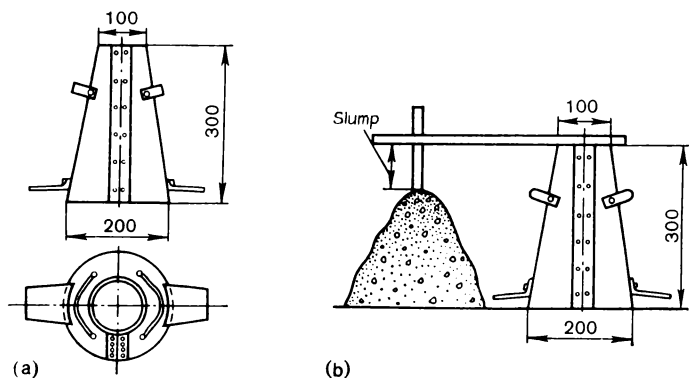


Fig. 23. (a) standard cone for determining the consistence of a concrete mix and (b) measuring the slump of a cone of concrete

largely govern the quality and properties of the concrete obtained from it. Special properties of a mix are its workability and plasticity.

The workability of a concrete mix is judged by its consistence or stiffness.

The consistence (mobility) of a concrete mix is its ease of flow under its own weight. The degree of consistence of a mix is judged by the degree of dropping of a cone formed from it. To determine the consistence of a mix (with a maximum size of the aggregate of 40 mm) a standard cone (Fig. 23a), which is a metal mould (without a bottom) in

the shape of a truncated cone 300 mm high, 100 mm in diameter at the top and 200 mm at the bottom. The mould, first wetted on the inside with water, is placed on a flat plate and filled through the top opening with three layers of concrete equal in height, each layer being rammed 25 times with a metal ram.

After the placing and ramming of the last layer, the surplus mix is smoothed off with a trowel even with the edges of the mould. The mould is then raised vertically by hand and removed, and placed beside the formed cone of concrete mix. After removal of the mould the mix settles. The amount by which the concrete cone drops below the top of the mould is measured and is called the slump (see Fig. 23*b*). The greater the slump, the higher the consistence of the mix.

Concrete mixes are classed, according to the amount of slump (in centimetres) into stiff (not slumping); low slump (a slump of 1 to 3 cm); plastic (a slump of 4 to 15 cm); pourable (slump greater than 15 cm).

The stiffness of a concrete mix is its capacity to flow and fill a mould under the impact of vibration. It is described by the vibration time (in seconds) that it takes for a freshly mixed concrete cone to spread horizontally in a mould.

The stiffness of a mix with a maximum size of the aggregate of 40 mm is measured by means of a viscometer (Fig. 24). The cylindrical vessel of the viscometer is placed and clamped on a standard vibroplate. A ring is then put into the vessel and clamped to it. A standard cone without lower clamps is placed on the ring, a packing fitted, and the cone filled with concrete mix and compacted, as when determining consistence. Finally the mix in the cone is compacted by vibration until separation of the cement is noticed on its surface under the bottom of the cone (in not less than five seconds and not more than 30 seconds).

At the end of vibration, the packing is removed, the surplus mix is smoothed off with a metal rule flush with the edges of the cone, and the cone then lifted straight up. After that a tripod with a rod and disc are fitted to the instrument, and the set screw of the rod unscrewed and the disc allowed to rest on the surface of the cone of concrete mix formed. At the same time the vibroplate is switched on and a stopwatch started. When the notch on the rod coincides with the upper surface of the guide ring of the tripod, the stopwatch is stopped, the vibrator switched off, and the time, elapsed since it was switched on, noted. This

time (in seconds) is the stiffness factor of the concrete mix.

Mixes are classed according to stiffness into very stiff (more than 200 s), stiff (30 to 200 s), and slightly plastic (15 to 25 s).

Plasticity (cohesion) is the property of a concrete mix not to demix during transporting, discharging and placing.

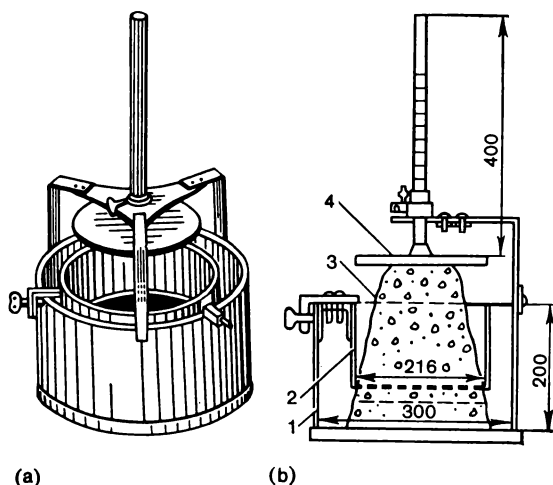


Fig. 24. Viscometer for determining the stiffness of a concrete mix (a) general view; (b) section; 1—vessel; 2—inner ring; 3—concrete mix shaped into a cone; 4—rod and disc

A wet mix that lacks cohesion will readily demix, lose homogeneity, and become unfit for placing in a form. The plasticity of a mix is guaranteed by proper choice of the components, above all of the necessary amount of cement paste.

Concrete. The main properties of hardened heavy concrete are strength, compactness, impermeability (watertightness) and frost resistance.

Compressive strength (grade). This is the index of the mechanical properties of a concrete. It is measured by the ultimate stress in compression of standard sample cubes $150 \times 150 \times 150$ mm, prepared from the concrete mix concerned and tested for 28 days in normal conditions.

The normal (standard) conditions for testing concrete samples are created in special chambers in which the tem-

perature is held at 15 to 20°C, and the relative humidity of air at not less than 90 per cent.

The grade of a concrete can be determined from cubes with edges of 100, 200, and 300 mm, apart from the standard cube described above. When such test samples are used the values obtained have to be reduced to the control characteristics of the standard cube by multiplying by the following conversion factors: 0.91, 1.05, and 1.1, respectively. When the size of standard cubes is being decided, account must be taken of the maximum size of the aggregate in the concrete: it should not exceed $1/3$ of the length of the side of a standard cube.

The following grades of concrete are established according to their compressive strength (in kgf/cm²): 100, 150, 200, 250, 300, 400, 500, and 600.

The compressive strength of a concrete depends mainly on the chemical activity of the cement, the ratio of water and cement (water-cement ratio W/C, or cement-water ratio C/W), and also on the strength and quantity of aggregate, its grading, the period of curing and hardening, the temperature and humidity of the environment, and other factors.

The strength of a 28-day, normal-cured concrete with a water-cement ratio ≥ 0.4 , knowing the activity of the cement, W/C ratio, type and quality of the aggregate, is:

$$R_{con} = AR_{cem} \left(\frac{C}{W} - 0.5 \right)$$

and with $W/C < 0.4$

$$R_{con} = A_1 R_{cem} \left(\frac{C}{W} + 0.5 \right)$$

where R_{con} is the grade of the concrete in kgf/cm²; R_{cem} is the activity of the cement in kgf/cm², A and A_1 are the factors allowing for the quality of the material (see Table 6).

The grading of the aggregate also affects the strength of a concrete. The strongest concrete is obtained by using coarse aggregate with a ratio of sand and gravel (or broken rock) that will provide a minimum of voids in their mix. In that case the consumption of cement will be minimal. In addition, the large particles of the aggregate must be quite strong and have a rough surface that will ensure good bending of the cement paste and the aggregate.

The strength of a concrete depends on the time it takes to harden and the curing conditions. Well-compacted concrete gains in strength, given favourable temperature and

Table 6

Values of Coefficients A and A_1

| Aggregate and cement | A | A_1 |
|----------------------|------|-------|
| High quality* | 0.65 | 0.43 |
| Normal** | 0.60 | 0.40 |
| Low quality*** | 0.55 | 0.37 |

* Crushed stone from solid rock of high strength, sand of optimum coarseness, and high-activity portland cement without additives or with a minimum amount of hydraulic additive in its composition; aggregate clean and graded.

** Average quality aggregate, including gravel, portland cement of average activity, or high-grade blast-furnace portland cement.

*** Coarse aggregate of low strength, fine sand, low-activity cement.

humidity conditions, over a considerable time. In the first seven to ten days its strength increases quite rapidly, then the increase in strength becomes slow, and finally ceases altogether after a year. Concrete samples, for example, kept in normal conditions for seven days have an average strength of 60 to 70% of the 28-day (standard) level; for 180 days, one year, and for two years, their strength corresponds to 150, 175 and 200% of the standard strength.

The following approximate empirical formula can be used to determine the strength of a concrete at any period of its hardening:

$$R_n = R_{28} \frac{\log n}{\log 28}$$

where R_n is the strength of the concrete at n days in kgf/cm^2 ; R_{28} is its strength at 28 days, in kgf/cm^2 ; n is the number of days of hardening of the concrete.

The actual strength of the concrete in structural members is determined by testing control samples made from the same concrete mix and cured in conditions similar to those of the member. Besides, the strength of the concrete of structural members can be determined, without destroying them, by means of various mechanical instruments (Fizdel's ball hammer; the Mosstroy Research Institute's standard hammer), and ultrasonically.

The temperature of the environment has a powerful effect on the rate of increase of a concrete's strength. At a temperature of 70°C to 85°C, in an atmosphere of saturated vapour, concretes will reach 60 to 70% of the standard

strength in ten to twelve hours. At 5°C to 7°C the rate of increase in strength slows, and at a temperature below 0°C hardening ceases.

Porosity of concrete ranges to 5-15%. The pores present in a concrete are formed as a result of evaporation of surplus water and incomplete deairing of concrete while compacting.

The density of concrete is increased by careful choice and grading of the particle size of the aggregate and the use of plasticizers which lower the water content of the mix. With increased density, the quality of a concrete is also raised, i.e. its watertightness, frost resistance, and corrosion resistance.

Watertightness is characterized by the degree of permeability, i.e. by the lowest pressure of water at which it will seep through a concrete sample. Concretes are graded as follows, according to permeability: W2, W4, W6 and W8, the figures indicating that given concretes will be watertight at a pressure not less than 2, 4, 6 and 8 kgf/cm². To improve the watertightness of a concrete, silicones are added to the mix, and other additives that promote compaction of the cement paste (e.g. sodium aluminate, chlorine iron).

Frost resistance is an important property of concretes that must be taken into account when reinforced-concrete structural elements are designed for the conditions of alternating wetting and freezing. Concrete is graded for frost resistance by the maximum number of cycles of freezing and thawing that a sample will withstand without breaking up.

There are five grades of frost resistance for heavy concretes, viz., Fr50, 100, 150, 200, and 300 (the number indicating how many cycles of freezing and thawing the concrete will withstand without breaking up). The frost-resistance grade of concrete is specified depending on the type of structural member, class or structure, and the conditions in which it will be exploited. An Fr50 concrete is usually used for the structural elements of housing and industrial buildings.

8.3. The Mixing, Transportation, and Placing of a Concrete Mix

The main technological processes of concreting and reinforced-concrete work are the mixing, transportation, placing, and compaction of the concrete mix, the subsequent curing of the concrete, and control of the strength.

Before the concrete mix is prepared, the most rational ratio of its components (cement, water, sand, gravel, or crushed rock) is established. This ratio must ensure the required workability of the concrete mix with the method adopted for compacting it, and ensure that the concrete reaches the specified strength in the given period with a minimum consumption of cement. For that purpose, formulas are calculated in the laboratory, or specially compiled tables of the water-cement ratio are employed. The water requirement of the mix is determined from the tables, allowing for the type and size of the aggregate, i.e. the amount of water to be used per cubic metre of the mix. The composition of the concrete as calculated is checked by sample mixes, and the results of testing control samples.

In the USSR the mixing of concrete is concentrated, essentially, in automatic concrete-mixing works, and in the concrete-mixing plants of enterprises making precast reinforced concrete, which supply several building sites with mixed concrete. Sometimes concrete is prepared on site in concrete mixers.

The business of mixing concrete consists in batching all the components and mixing them to obtain a uniform mass. In mixing works and units the materials are batched by semi-automatic weighing batchers that ensure a high accuracy of batching, rapidity of weighing, and ease of control.

The components are mixed in concrete mixers of cyclic and continuous operation. There are two ways of mixing: by free fall of the materials or by forced stirring or agitation.

To prepare a plastic concrete mix, batch mixers are employed with free fall of the materials. They have a tilted drum with a capacity of 100, 150, 250, 425, 1 200, and 4 500 litres; mixers up to 250-litre capacity are mobile, and bigger ones, stationary (Fig. 25). The main working unit of these mixers is the rotating drum with blades or baffles on the inner surface. When the drum is rotated the materials dumped into it are caught by the blades and raised slightly; then in falling they are mixed to form a uniform concrete mix.

Cyclic mixers with forced stirring are used to prepare stiff concrete mixes. In them the components are stirred in a horizontal rotating drum. Within the drum are blades rotating in the opposite direction to the drum. The mixed concrete is extracted through a hatch in the bottom of the drum.

In recent years continuous mixers have been installed in concrete-mixing plants, which consist of a cylindrical drum with internal baffles. Because of the rotation of the

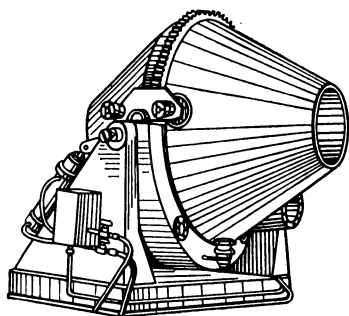


Fig. 25. Stationary tilting concrete mixer with a 2 400-litre drum

drum and the helical direction of the baffles the materials are shifted along the drum and thoroughly mixed; the ready mix is discharged in a continuous flow into the means used for transport. Continuous mixers have a high productivity up to 120 m³/h, while cyclic mixers with a capacity of 2 400 litres have a productivity up to 36 m³/h.

The uniformity and strength of concrete largely depend on the quality of the stirring of the mix; the order of charging

a cyclic mixer must be strictly followed, and the optimum mixing time established experimentally in the laboratory observed.

Water (15 to 20 % of the total volume required in the batch) is first fed into the mixer, then the cement and aggregate are charged, without interrupting the running-in of water to the required amount.

With free-fall mixers the mixing time of plastic cement is roughly one minute for a 425-litre or smaller drum, two minutes for a 1 200-litre drum, and 2½ minutes for a 2 400-litre drum. The mixing time of a stiff concrete should be increased by 50 to 100% that of plastic mixed.

Precautions against disintegration must be taken when the mix is being discharged from a mixer. The discharge chute or tube is so placed that the flow of the mix is directed vertically into the centre of the transmitting vessel (e.g. bunker, bucket, tub, body of a tripping lorry).

Mixed concrete is usually transported from a concrete works or mixing plant to the site by tripping lorries, but over short distances (on a building site) by belt conveyers, concrete pumping machines, buckets, etc. Transmission time should not exceed 90 minutes, in order to avoid disintegration and lowering of the plasticity of the mix (through evaporation, escape of cement grout, or setting of the cement). Precautions against the action of rain or snow, sunshine,

and, in winter, of freezing, must be taken during transportation.

The quality of concrete and reinforced concrete structural elements largely depends on the mode of *placing* and *consolidation* of the mix. Mixed concrete is usually placed in the previously prepared shuttering (formwork) in which the reinforcement iron has been fixed, and consolidated by vibration. The essence of vibration is the transmission of high frequency vibrations to the mix by means of special mechanisms (vibrators), as a result of which the viscosity of the mix is considerably reduced. This thinned-out mix spreads evenly by the force of gravity in the form, fills all the interstices between the reinforcement and is well consolidated. During vibration the large particles of the aggregate are compacted and the interstices between them filled with concrete paste, while air bubbles are forced out. When the vibration ceases, the concrete mix, placed in the shuttering or formwork, instantly sets.

The choice of vibrator type (table, internal, or platform) is determined by the type, form, and size of the concreted structure; for structures with a big open surface (e.g. floors, or slabs) table vibrators are used (see Fig. 26a); for massive constructions (e.g. foundations), internal (immersion) vibrators are used with a flexible driving shaft and needle vibrators (Fig. 26b, c).

The length of vibration time in any position must be sufficient to ensure adequate compacting of the concrete, the main signs of which are cessation of settling of the mix, the appearance of a film of glistening paste, and cessation of the escape of entrained air bubbles.

The hardening and curing of concrete. Concrete placed in shuttering or formwork gains in strength over quite a long period. In normal conditions (temperatures of 15°C to 20°C and a humidity of 90 to 100%) concrete reaches the standard strength in 28 days. Hardening is accelerated considerably by raising the temperature to 70-85°C (necessarily with retention of moisture in the concrete). In dry conditions concrete quickly loses moisture and its further hardening is suppressed.

With correct curing, placed and consolidated concrete reaches the required strength within the specified period. Freshly placed concrete is kept in a moist state and protected against vibrations, shocks and impacts, damages of any kind, and sharp changes of temperature. In summer the

open surfaces of freshly placed concrete are covered with sacking, sand, sawdust, or other materials, and periodically wetted.

The shuttering of concrete and reinforced concrete work is dismantled after the concrete has reached a certain strength (which is ascertained by testing control samples).

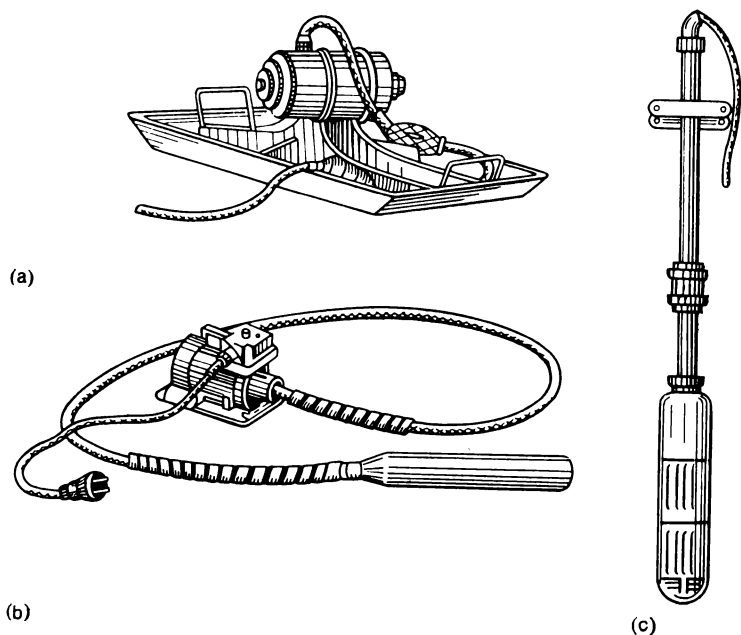


Fig. 26. (a) surface (table) vibrator; (b) internal vibrator with flexible driving shaft and (c) needle vibrator

The hardening of concrete is slowed down considerably at temperatures below 5°C , and below zero it ceases altogether. The main condition for concreting work in winter is to ensure a certain raised temperature in the placed concrete that will prevent it from freezing in the early stages before it reaches 50% of the standard strength.

To prevent early freezing of concrete and to ensure its hardening at low temperatures, various methods of winter concreting have been developed and introduced. Today the following methods are used: the 'thermos' method, steam and electrical heating, and use of concrete with chemical

additives (hardeners). Each method can be used by itself or in combination with others.

To check the strength of hardening concrete, control samples are employed cast from the same mix, and hardening in the same conditions as the concrete of the monolithic, cast structures. The samples are tested after 7 and 28 days, or at some other fixed period.

There are now several mechanical and physical methods to determine the strength and uniformity of the concrete in various spots in reinforced concrete structures without rupturing them. In order to discover hidden internal defects in the structure of a concrete (e.g. cracks, cavities, or voids), special ultrasonic flaw detectors are used.

In areas with a dry hot climate concreting work has its special features. At an external temperature of 35°C to 45°C, and a relative humidity of 10 to 25 %, intensive solar radiation, and frequent winds, concrete is subject to rapid dehydration, which leads to a slowing, even cessation, of hardening. Premature dehydration has a deleterious effect on the strength of concrete, in tension and bending; the concrete itself becomes porous, shrinkage cracks arise, and the watertightness of the concrete is markedly reduced.

Quality monolithic reinforced concrete elements can be obtained in a dry hot climate by employing a set of special design and technological measures. Great attention must be paid, moreover, to the design of concrete mix. Portland cement with an admixture of calcium chloride should be used. Portland blast-furnace cement and portland pozzolana cement are not recommended.

For concretes to be used in a dry hot climate, it is advisable to use aggregate from dense carbonate rocks, since they bond well with the cement stone and are close to it in the values of the coefficient of thermal expansion. It is not recommended to use aggregate from volcanic rocks, e.g. basaltic chippings, since it leads to a lowering of the strength of the solidified concrete. Aggregate should be shaded from sunshine before the concrete mix is prepared, and porous chippings should be wetted as well.

Mixing time for concrete is increased by 30 to 50 % in a dry hot climate. The mix is transported in concrete carriers or transit concrete mixers, the latter being preferred. At a central concrete-mixing works, the dry mix is loaded into a transit mixer which takes it in dry form to the site and the mix is stirred in the mixer directly at the point of concreting.

Before the mix is placed, the shuttering should be examined to see that there are no cracks or chinks through which cement paste and moisture can be lost. The inner surface of the shuttering should be wetted. It is advisable to place the concrete mix into the structure being concreted by means of a concrete pump or in big buckets shifted by crane. The free fall of the mix should not exceed $1\frac{1}{2}$ to 2.0 metres. It is desirable that the concreting be continuous; if there are interruptions special attention must be paid to the quality of the joint. The vibrocompacting must be carefully done so as to give the concrete a dense structure and reduce evaporation of water. Concreting should be carried out in the most favourable times of the day (e.g. in the evening, in the morning, or even at night).

The wetting is kept up to 28 days. Structural elements can also be strewn with damp sand or sawdust after concreting is completed, and the sand or sawdust regularly damped. The high-moisture materials of the cover for concrete, and wooden shuttering should be kept continually damp. The frequency of wetting for that needs to be decided in accordance with the temperature of the surrounded air. It is recommended to wet concrete every two hours in 24 h, when the maximum air temperature is between 30 and 35°C, every 90 minutes when the temperature is between 35 and 40°C, and every hour with a temperature above 40°C. At night the interval between wettings can be doubled in length.

Because regular moistening of concrete during its curing is attended with significant outlays, where water is short, it is advisable to employ so-called moistureless methods of curing. One of these is to keep the concrete under special air-tight plastic (PVC) hoods, or to cover the surface of the concrete with special film-forming compounds.

When concreting work is being carried out in a dry hot climate, it is necessary to arrange laboratory control over the quality of the concrete.

8.4. Lightweight Concretes with Porous Aggregates

Types of lightweight concretes. Concretes with porous aggregates are now the most commonly used types of lightweight concrete. Unlike ordinary dense concrete, its density does not exceed 1 800 kg/m³, because of the use of light,

porous aggregates. Lightweight concretes with porous aggregates are employed, because of their low unit weight and low coefficient of thermal conductivity, to make precast concrete and reinforced concrete units and structural elements. There are various types of concretes made of lightweight porous aggregates, the types being distinguished by the kind of aggregate used, the structure of the concrete itself, and its purpose.

Depending on the type of lightweight aggregate used, the concretes are distinguished as expanded-clay, slag, pumice concretes, etc.

Lightweight concretes are divided into the following main types, according to their structures:

(a) ordinary lightweight concretes prepared from a binder, water, fine and coarse aggregate with full filling of the voids between the large particles (Fig. 27);

(b) low-sand concretes, in which the voids between the coarse aggregate are only partially filled with the paste;

(c) no-fines (coarse aggregate) concretes, in which the coarse particles of the aggregate are covered by a thin layer of cement paste, and the voids between them remain empty;

(d) aerated concretes made from a binder, water, fine and coarse aggregates, and a blowing agent which increases the porosity of the cement paste and so reduces the density of the concrete.

Lightweight porous concretes are divided into the following types, depending on their purpose:

(a) thermal-insulating with a density in the air-dry state of less than 500 kg/m^3 , used to make insulating plates and other units;

(b) constructional-insulating with a density of 500 to $1\,400 \text{ kg/m}^3$, used for load-bearing and self-bearing enclosing elements (walls and roof slabs);

(c) constructional, with a density of $1\,400$ to $1\,800 \text{ kg/m}^3$, used for load-bearing elements (roof slabs, surfacing slabs, etc.).

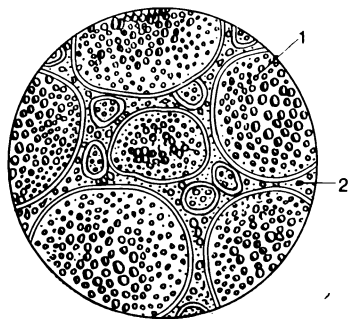


Fig. 27. Structure of expanded-clay concrete

1--grains of expanded clay; 2--mortar

In making lightweight concretes the type of binder is selected in accordance with the hardening conditions (natural hardening, steam curing, or autoclaving) and the required strength of the concrete, the durability needed in the service conditions, and other factors.

For lightweight concretes (other than autoclave-hardened), portland cement, portland blast-furnace cement, portland pozzolana cement, and fast-hardening portland cement (whose properties were described earlier in Chapter 5) are used.

Aggregates for lightweight concretes. Natural or artificial loose porous stony materials are used; the properties of the prepared concrete depend in large measure on their properties and quality.

Natural aggregates are obtained by crushing and grading rocks (pumice, tuff, or lava, shell limestone, tufa, etc.). The most effective of these are pumice and tuff, which have a high, mainly closed, porosity, so that their water-absorption is minimal.

Natural aggregates are the most economical when they are local materials and do not call for sizeable outlays on transport to carry them to the site of consumption.

Artificial aggregates are obtained from the wastes of industry, and through special treatment of natural rock materials.

Aggregates that are wastes of industry and usable without preliminary treatment are slag from steel works, the slags formed during the gasification of coals, slags of the chemical industry, and the clinker from lump combustion of various types of coal.

Aggregates obtained by special processing of natural rock materials and industrial wastes include expanded clay, expanded perlite and vermiculite, slag pumice, granulated slag, etc.

The aggregates may have a rounded, relatively smooth surface (expanded-clay gravel) or an angular, rough surface (crushed slag pumice). In particle size porous aggregates are divided into fine (sand) and coarse (gravel or crushed rock). Porous sand is usually sieved into two fractions, viz., under 1.25 mm (fine sand) and between 1.25 and 5 mm (coarse sand). Crushed rock (or gravel) is graded into three fractions: 5-10, 10-20, and 20-40 mm. The proportion of each fraction in the mixture of aggregates is established by means of special tables (graphs) computed to yield a mix with the minimum amount of voids.

Porous aggregates are graded as follows by bulk weight (in the dry state): grades 100, 150, 200, 250, 300, 350, 400, 500, 600, 800, 1 000, and 1 200.

The strength of crushed rock or gravel, as determined by a special technique of crushing it in a steel cylinder, varies between 0.4 and 20 MPa. When natural aggregate is prepared by crushing porous rock, its strength must be not less than 50% of the required strength of the concrete, and the wet-to-dry strength ratio must not be less than 0.6.

The amount of harmful impurities that will cause corrosion of the set concrete and lower its resistance in service conditions must not exceed the permissible values.

Harmful impurities include water-soluble sulphides and sulphates, particles of unburnt fuel, and clayey and pulverised particles.

The properties of lightweight concretes. The principal properties of lightweight concretes with porous aggregates are their density, heat conductivity, strength, and frost resistance. In order to produce a lightweight concrete with the specified properties, it is necessary to select the composition of the concrete correctly as well as the initial components.

The density of a lightweight concrete depends largely on the unit density and particle size of the aggregate, and the amount of binder and water used. The ratio of the bulk density of loose coarse aggregate to the density of the concrete made from it is 0.5 for ordinary lightweight concrete and 0.6 for no-fines and porous concrete. If, for example, expanded clay aggregate with bulk density of 500 kg/m^3 is used, an expanded-clay concrete can be obtained with a density around $1\,000 \text{ kg/m}^3$.

The density of a lightweight concrete rises with an increase in the amount of binder used, since the density of the porous aggregate is less than that of cement. In order to reduce the density of the concrete it is necessary, by selecting the optimum grain size of aggregate, to ensure the minimum consumption of binder for concrete of the specified strength. The density and heat conductivity of a concrete can be reduced by the forming of fine, closed pores in the cement paste. It is advisable to mix foamed lightweight concrete from a porous aggregate of density more than 500 kg/m^3 .

Thermal conductivity of lightweight concrete (K-value) varies in value from 0.07 to $0.76 \text{ W/(m}^\circ\text{C)}$. The K-value is affect-

ed by the density of the concrete, the character of the porosity, and other factors. It rises with an increase in the density of the concrete.

The *strength* of a lightweight concrete depends in the main on the activity of the cement, the water/cement ratio, and the strength of the aggregate, also on the amount of cement used and the degree of consolidation of the concrete. The higher the amount of cement stone in concrete, the higher its strength, but the density of concrete increases with the amount of cement it contains, and at the same time its thermal conductivity rises, which is undesirable.

Mixing and use of lightweight concretes. Concrete mixes with porous aggregate are prepared in the same way as ordinary mixes, except that the lightweight mix must be more carefully stirred, for which purpose a concrete mixer is usually used that works on the principle of forced mixing.

When units are being made from a lightweight mix the same mode of placing it in forms and consolidating it are used as for units made from dense mixes. Items made from lightweight mixes are quite intensively hardened by steaming or electric heating or are autoclaved.

Concretes with lightweight porous aggregate are now widely used to make blocks and panels for the bearing walls of housing, floor and roof slabs; precast reinforced elements for the superstructure of bridges, girders, and trusses, etc., are made from high-strength grade 200-400 expanded-clay concrete.

8.5. Aerated Concrete

Forms of aerated concrete. Aerated, or cellular, concrete is an artificial stone material consisting of a solidified binder with an even distribution in it of closed pores in the form of cells not more than 1 to 2 mm in diameter, that are filled with air or gas. The pores constitute up to 85 per cent of the volume of the concrete and are evenly distributed throughout it and divided from one another by thin, strong films of cement stone or other binder (Fig. 28).

There are many varieties of aerated concrete. They differ in the means of obtaining the pores, types of binder, hardening conditions, and in purpose.

Depending on the means by which their porous structure is formed, aerated concretes are divided into gas concrete and foamed concrete.

As binders for aerated concretes, portland cement, air-hardening lime, slag and gypsum are used.

Aerated concretes are of two types, according to the siliceous component used: gas silicates, foam concretes, etc., obtained using pulverised sand, and gas silicates, gas-ash concretes, foamed-ash concretes, obtained by using fly ash instead of sand. Aerated concretes are autoclaved (factory-made variety) or non-autoclaved, (site-cast variety), according to the way they are cured.

Aerated concretes are divided into the following types, according to their field of application:

(a) insulating concretes with a density in the air-dry state of less than 500 kg/m^3 , used for making heat and sound insulating plates, shells, and other units;

(b) constructional insulating concretes with a density between 500 and 900 kg/m^3 , used for cladding of buildings;

(c) constructional concretes with a density between 900 and $1\,200 \text{ kg/m}^3$, used for making load-bearing structures.

The properties of aerated concretes. Strength and density are the main indexes of the quality of an aerated concrete. Density varies from 300 to $1\,200 \text{ kg/m}^3$, and is indirectly described by its porosity (correspondingly 85 to 50%). An increase in the density of an aerated concrete leads to an increase in its strength.

The thermal conductivity of aerated concretes depends on their density. The coefficient of heat conductivity for insulating concretes is 0.1 to $0.2 \text{ W (m } ^\circ\text{C)}$, and for constructional insulating concretes of a density of 700 to 900 kg/m^3 it is 0.24 to $0.44 \text{ W (m } ^\circ\text{C)}$.

The water absorption and frost resistance of aerated concretes depend on their density and the structure of the pores. With a density of 700 to 900 kg/m^3 , water absorption (by mass) varies between 20 and 35% . The frost resistance of aerated concretes is rather lower than that of lightweight concretes.

Aerated concretes have good sound-insulating properties

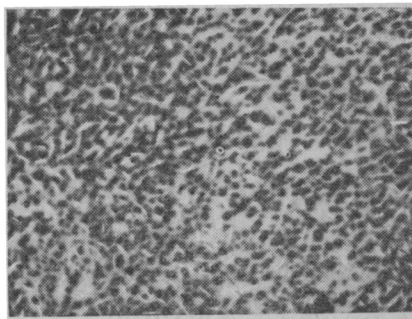


Fig. 28. Structure of aerated concrete

and fire resistance, and are easily worked (nailed and sawn).

Uses of aerated concretes. Heat-insulating aerated concretes are used as panels, blocks, shells to insulate the exterior structures of buildings, and to insulate refrigerators and the surfaces of refrigerating plants.

Constructional-insulating aerated concretes are used to make single-layer wall panels, etc.

Constructional reinforced aerated concretes, which have very high bending strength, are used for load-bearing (and simultaneously insulating) roofing of industrial buildings, interstorey ceiling floors, etc.

Chapter IX

Precast Concrete and Reinforced Concrete Articles

9.1. General Data on Reinforced Concrete

Precast concrete and reinforced concrete units and structural elements are now widely used in the construction industry.

Reinforced concrete is a building material in which hardened concrete and steel reinforcing are combined in a single whole. Concrete has a good bending strength but poor tensile strength; steel reinforcing has a good tensile strength.

A diagram of the work of a reinforced concrete beam is shown in Fig. 29. The beam, resting on two supports and under stress from above, experiences compression in the upper zone and tension in the lower. The strength of a beam made only from concrete is not great; because of the low resistance of concrete to tension the beam breaks under a small load. When there is steel reinforcement in the lower, tension zone the beam can support a considerable load. The joint work

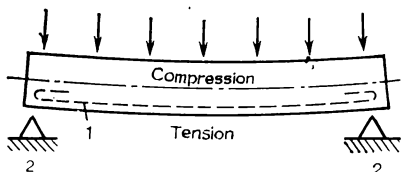


Fig. 29. Diagram of bending of a reinforced concrete girder
1—steel reinforcement; 2—supports

under stress from above, experiences compression in the upper zone and tension in the lower. The strength of a beam made only from concrete is not great; because of the low resistance of concrete to tension the beam breaks under a small load. When there is steel reinforcement in the lower, tension zone the beam can support a considerable load. The joint work

of reinforcement and concrete is conditioned by the great strength of the bond between them. In addition, the reinforcement in a dense concrete is well protected against corrosion.

Reinforced structural elements are divided, according to the way they are made, into cast-in-situ (monolithic) and precast. The former are made directly on the jobsite; a great deal of manual labour and materials are expended on making shuttering, scaffolding, etc.

Precast reinforced structural elements are often much more economical than cast-in-situ ones, since they are made in special factories or casting yards. The use of precast reinforced concrete elements makes it possible to convert a building site into an assembly and erection one, reduce the labour cost of concrete and reinforced concrete work, improve its quality and reduce costs.

9.2. Steel in Reinforced Concrete

Reinforcement steel is the most important component of reinforced concrete, and must function reliably together with the concrete throughout the service life of the element or structure. It is mainly placed in that part of the unit that will be subjected to tensile forces which it must take up.

Reinforcement steel is classified according to the way it is made (hot-rolled rods and cold-drawn wire), the cross-section of the rod (smooth or deformed), and the field of application (stressed and unstressed, i.e. used either in an ordinary or pre-stressed reinforced concrete element). The use of elements with pre-stressed reinforcement makes it possible to reduce their weight, improve their crack resistance and life, and to reduce expenditure of steel. Certain types of reinforcement steel are shown in Fig. 30.

Reinforcement bars come as hot-rolled, cold-drawn, and thermal hardened.

Hot-rolled steel for reinforcing concrete structural elements is divided into various classes according to its mechanical properties. The conventional Soviet symbols for hot-rolled reinforcement bars are: A-I, A-II, A-III, A-IV, and A-V.

Reinforcement bars are made in rods or bundles. A-I bars are round and smooth, those of classes A-II, A-III, A-IV, and A-V are deformed (indented).

Indented bars are round rods with two longitudinal ribs and transverse projections following a triple-start helical line. For rods of 6 to 8 mm in diameter, the projections can be double-helix or double-start.

Reinforcement steel is made, in accordance with its class and diameter of bars, from carbon, or low-carbon steel.

Reinforcement steel of class A-I and A-II under 12 mm in diameter and of class A-III up to 10 mm in diameter

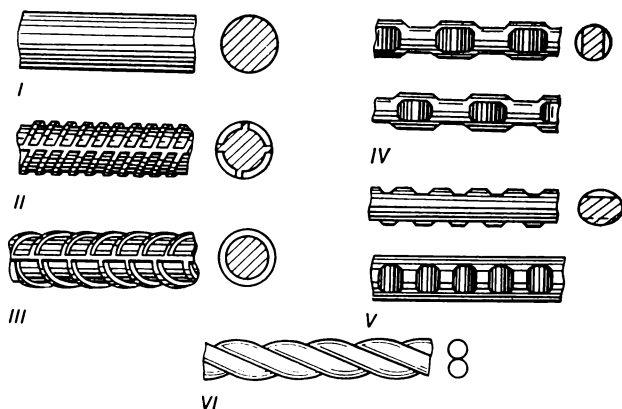


Fig. 30. Types of reinforcement bars

I—smooth; II—hot-rolled indented (class A-II); III—the same, class A-III; IV—with four cold-flattened sides; V—the same, with two flattened sides; VI—spiral type

come as rods or bundles: steel of the same grade but of large diameter is made in round rods; so are the other grades (A-IV and A-V).

Wire reinforcement is divided into reinforcement wire and reinforcement wire products. Wire is supplied in bundles or reels, each reel consisting of one length of wire. Wire must be protected against damp during transportation and storage.

Reinforcement wire is made from mild steel (used to reinforce concrete structural elements), and carbon steel, which is used to reinforce prestressed concrete elements.

Reinforcement wire is produced in diameters between 3 and 10 mm, smooth or indented. Indented wire is obtained by repeatedly indenting its cylindrical surface along the central line.

Reinforcement wire-mesh is used in building and in making reinforced concrete elements in the form of locked steel reinforcement strands, steel reinforcement cables, and welded reinforcement meshes.

Normal precast reinforced concrete members and structural elements are mainly reinforced by welded meshes or cages. Panels and slabs, for example, are reinforced by flat meshes (Fig. 31a), reinforced concrete joists, bearers, etc., of rectangular section, by plane frames (Fig. 31b), rectangular beams, T-beams, I- and H-beams, by cage frames (Fig. 31c), and reinforced concrete pipes by circular cage frames (Fig. 31d).

Precast reinforced concrete units, as a rule, have embedded fittings by which they can be joined together during assembly; they are steel plates with anchors welded onto them in the form of steel rods. The anchors can, in addition, be welded to the reinforcement steel of the member.

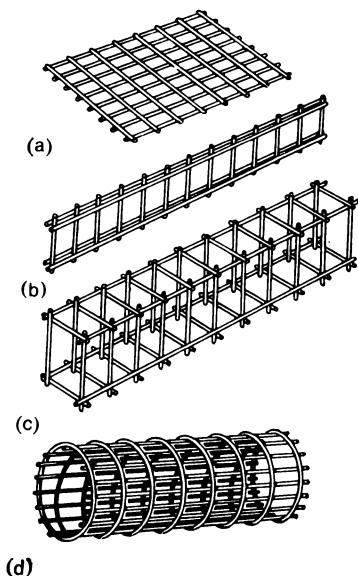


Fig. 31. Reinforcing units

(a) wire-mesh reinforcing; (b) plane frame; (c) reinforcing cage of rectangular section; (d) the same of circular section

9.3. Structural Steel Shapes

Rolled steel shapes (angles, channels, I-beams, etc.) are widely used in construction. Rolled angles (Fig. 32) come in the form of equal angle and unequal-angle bars with legs of 20 to 250 mm; channels are 50 to 400 mm high with flanges 32 to 115 mm wide. I-beams come with ordinary and wide flanges. The ordinary I-beams are 100 to 700 mm high, wide-flanged ones up to 1 000 mm. The ratio of the width of flange to the height varies from 1 : 2 (with low heights) to 1 : 3 (with great heights).

The types of rolled shapes mentioned above are used to make various welded or rivetted structural members (frameworks, and trusses and girders for industrial and

public buildings, bridge superstructures, floor beams, pylons for power transmission, sky-lights for buildings, etc.). In addition, rolled and stamped steels of special shapes are used to make the window casements of industrial and civil buildings.

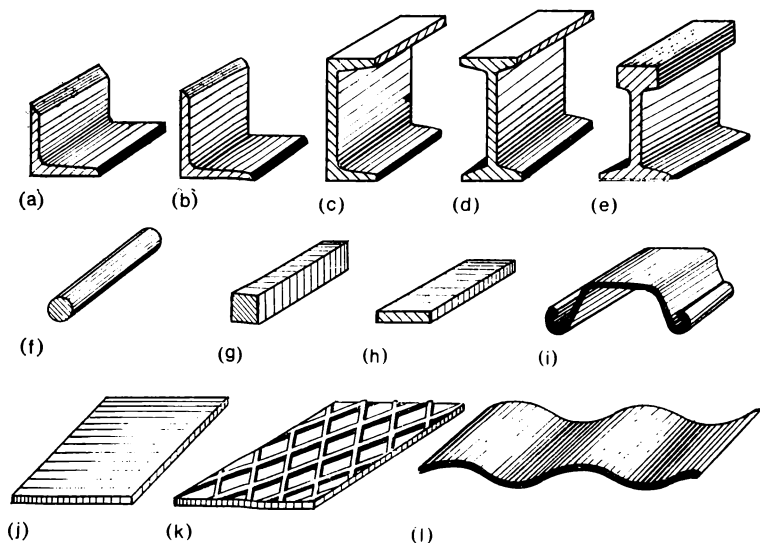


Fig. 32. Reinforcement steel shapes

(a) equal angle; (b) unequal angle; (c) channel; (d) I-beam; (e) rail; (f) round; (g) square; (h) strip; (i) sheet pile; (j) sheet; (k) rippled; (l) corrugated

Rolled steel of a square or round cross section, and strip steel are used in building for various purposes. Round steel is mainly used as reinforcement for concrete.

There are several kinds of rolled steel plate and strip; those most commonly used in building are rolled plates 600 to 3 800 mm wide and 4 to 160 mm thick, sheet steel and strips 600 to 1 400 mm wide and 0.5-4 mm thick; roofing sheets (usually galvanized), 510 to 1 500 mm wide and 0.5 to 2 mm thick; and also corrugated and chequed sheets.

Steel sheet piling is made in various shapes and is used for hydraulic engineering work.

Seamless and welded tubes are made in diameters from 50 to 1 620 mm, and are used for gas and oil pipelines, water, and heating mains, etc.

Small hardware items, such as bolts, nuts, washers, rivets, are widely used in the fabrication of various structural elements from rolled steel shapes. No building site today can manage without steel fasteners (wood screws, screws, nails, clamps, etc.).

9.4. Types of Concrete and Reinforced Concrete Articles

For *housing* and *public buildings*, the following types of precast reinforced concrete elements are used: foundation blocks, basement-wall blocks, piles, posts, wall blocks and panels, flooring and roofing slabs, sanitary-engineering blocks, ventilation blocks, heating panels, prefabricated bathrooms, and other prefabricated reinforced concrete items.

Foundation blocks are made from dense concrete of grades 100, 150, and 200, and reinforced by flat welded meshes. For strip foundations, flat and trapezoidal blocks (pads) are made (Fig. 33a) and concrete basement-wall blocks (solid—Fig. 33b, or hollow—Fig. 33c). Blocks are rectan-

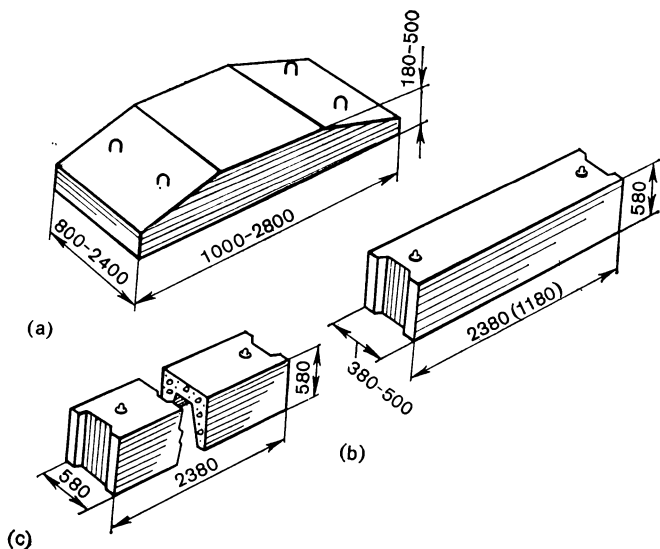


Fig. 33. Precast strip foundations
 (a) cushion block; (b) continuous block; (c) hollow block

gular in shape and have the following dimensions: length up to three metres, thickness 300 to 580 mm, height 580 mm. Grooves are made on the end faces, which are filled with mortar when the basement wall is being laid. Hollow blocks are more economical than solid ones.

For columnar foundation, cup-like blocks are used in which the columns of the building's frame are set.

Piles have a 300×300 mm square cross section and are 6 to 12 metres long. They are made from grade 300 concrete. The use of pile foundations for large-block and large-panel buildings saves considerably the erection time and reduces cost.

The framework of housing and public buildings is fabricated from reinforced concrete columns, beams, joists, and other elements made from dense concrete of grades 200 to 400. The length of columns is usually taken as the height of two storeys of the building. The columns are welded together and to the beams and joists.

Wall blocks are cast from lightweight concrete of grades 50, 100, 150, and 200 of a density not greater than 1600 kg/m^3 . The blocks of load-bearing and interior walls are made either solid or hollow. The thickness of the blocks of load-bearing walls depends on the climatic conditions, the number and forms of the cavities, and the heat-insulating properties of the concrete used, and varies between 300 and 500 mm; the thickness of the blocks of inner walls is from 200 to 400 mm. The height and width of wall blocks is selected according to the accepted number of block rows within the height of a storey (two or three), the lifting capacity of the available lifting mechanisms (cranes), etc.

The main system of sectioning walls from concrete blocks is the two-row system (Fig. 34), in which the wall is assembled from two blocks of different height, a partition block and a window block.

The partition blocks are spanned by lintels. There are thus two horizontal seams within the height of each floor.

Panels of load-bearing walls (Fig. 35) of a thickness under 350 mm are either single-module (the size of a room) or two-module (for two rooms), and are fabricated from lightweight and aerated concretes of grades 75 to 100.

The panels of inner walls are made from heavy concrete of grades 200 to 400. Their thickness depends on the design features of the building, the operative load, and the grade of concrete, and varies between 120 and 160 mm.

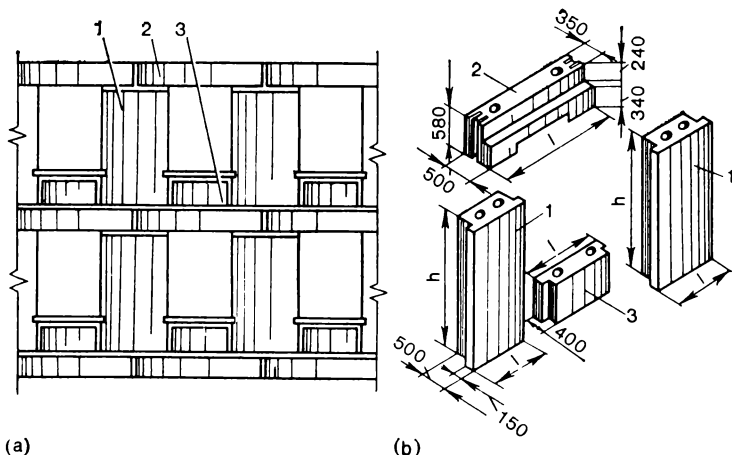


Fig. 34. Two-row view (elevation) of walls
 (a) division of the facade into blocks; (b) facade wall blocks; blocks: 1—partition;
 2—lintel; 3—window sill

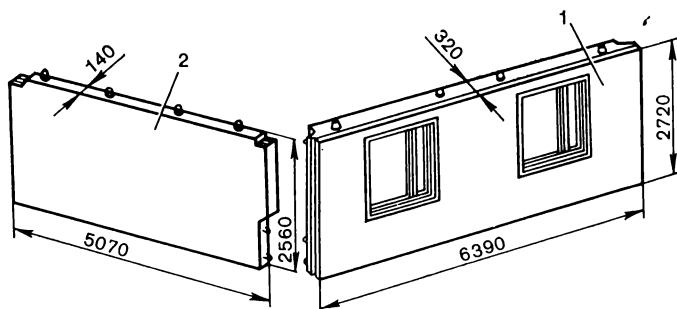


Fig. 35. Wall panels
 1—expanded-clay concrete exterior panel; 2—interior panel

Floor and ceiling panels may be flat solid or cavity panels (with round or oval cavities) up to 8 760 mm long, 3 580 mm wide, and 120, 160, 220, or 300 mm thick. They are made from heavy or lightweight concretes of grades 200 to 300 with ordinary or prestressed reinforcement.

Precast roofing panels and slabs are made ribbed or flat, from grade 150 or 200 concrete, up to 6 000 mm long, 1 500 to 3 000 mm wide.

Staircases and landings (Fig. 36) are made from grade 200 concrete and reinforced with welded meshes and frameworks. The dimensions of the steps and landings are fixed in accordance with the height of the storey and the width of the stairway.

Lintels used to span window and door openings are made from grade 150 concrete. Rectangular bars and panels support only the load of the masonry (or walling); strengthened bar lintels take a load from the walling, floor-ceiling panels, and other elements.

Balcony panels are flat rectangular, up to 3 200 mm long and 1 240 mm wide, made from grade 200 concrete.

Reinforced elements of a wide range are made for industrial buildings. The main ones are as follows.

Foundations for columns are made with the footing 1 300 to 1 900 mm long and 600 mm high from grade 150 to 200

concrete. A depression (cup) is cast in the centre of the cushion footing to take the column.

Foundation blocks are fabricated with a trapezoidal or T-shaped cross section. The section is 400 to 600 mm high, the length of the beam 4 450 to 10 700 mm. Grade 200 to 400 concrete is used, with ordinary or prestressed reinforcement.

Columns are designed as either solid single-piece or open-work two-piece, depending on the height of the building, the availability of cranes, and the lifting capacity of the latter. Columns (Fig. 37) are made with square, rectangular, or T-shaped cross sections sizing from 300 × 300 mm to 400 × 600 mm and over, from grade 200 to 500 concrete. In order to support crane beams, the columns of the outer rows of a building are given a single cantilever and those of the central rows, two. Columns are reinforced by a welded framework.

T-section crane beams serve as supports for the rails of overhead travelling cranes. They are made 12 000 mm long from grade 400 concrete with prestressed reinforcement.

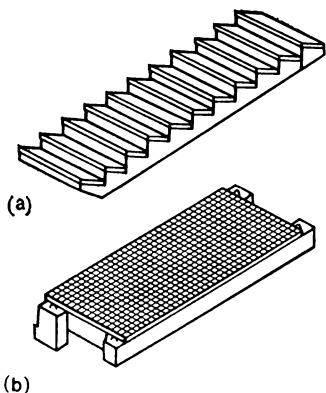


Fig. 36. Stair elements
(a) flight of steps; (b) landing

Roof beams (Fig. 38) are either double- or single-slope, with a rectangular, T-shaped, or I-shaped cross section. They are fabricated from concrete of grades 300 to 400 with pre-stressed reinforcement, and come in lengths of 12, 18, and 24 metres.

Roof girders and trusses are used as load-bearing elements for spans of 18 metres or more. They may have a trapezoidal, triangular, or curved-segment shape (Fig. 39).

Wall panels for unheated buildings are made in the form of ribbed (corrugated) sheets, and for heated premises from lightweight concretes; their designs and dimensions vary greatly.

Floor slabs and roofing slabs for industrial buildings are sometimes the same as for housing (e.g. flooring, panels). Reinforced ribbed slabs are used for flooring, in some cases

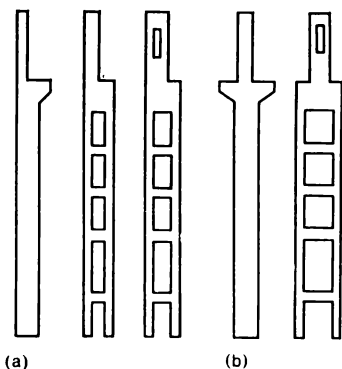


Fig. 37. Reinforced concrete columns for single-storey industrial buildings

(a) for single-cantilever exterior row;
(b) for two-cantilever inner row

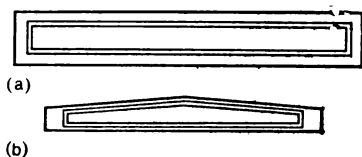


Fig. 38. Reinforced concrete roof beams

(a) single-slope; (b) ridged

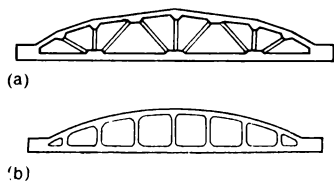


Fig. 39. Reinforced concrete roof trusses

(a) segmented; (b) unbraced

for roofing. Thin-walled reinforced concrete shells are being used frequently now to roof buildings.

9.5. Fabrication of Reinforced Concrete Elements

Precast reinforced concrete elements are fabricated in plants and integrated house-building factories, and also in mechanized casting yards. Factories and prefabrication yards contain the following: stocks of binder (cement), aggregate, and reinforcement; concrete and mortar-mixing

shops; reinforcement shops with stocks of ready-made meshes and frames; a shop for forming and hydrothermal treatment; stocks of finished product.

The principle processes in the fabrication of reinforced concrete elements. The production of reinforced concrete units includes the following main manufacturing processes: preparation of the concrete mix; fabrication of the reinforcement and reinforcing of elements; the forming, hydrothermal treatment, and quality control of the finished product.

Preparation of the concrete mix. The concrete mix is prepared, as a rule, in a concrete-mixing shop, or department, located in direct proximity to the forming shops. The features of preparation of mixes of various kinds were considered in Chapter VIII.

Fabrication of reinforcement. Ordinary unstressed reinforcement in the form of welded meshes and frameworks is fabricated in the reinforcement shop of reinforced-concrete factories. Reinforcement, which is brought to the factory in coils or as rods, is cleaned of scale and rust on special machines, straightened, and cut into rods of the required length. The rods are then bent on machines to the required shape. The separate rods are joined together in meshes and frames by welding. The ready meshes and frames are transported to the forming shop where they are placed in previously prepared forms.

Reinforcement is stressed in the forming shops where it is prestressed (before concreting) on stressing stands by means of hydraulic jacks or electrothermally.

The forming of elements. The forming of reinforced concrete members consists in the following main operations: cleaning, assembly, and lubrication of the form, placing of reinforcement in the form, placing and consolidation of the concrete mix in the form.

Forms are cleaned of residues of hardened concrete from prefabricated elements, assembled, and then lubricated by various emulsions that prevent adhesion of the concrete of the member to the metal of the form.

Concrete mix, prepared in the concrete-mixing shop, is transmitted to the bunker of a concrete-laying machine which delivers the mix to the form and levels it.

The concrete mix is compacted by various means: vibration, vacuum compaction, centrifugal compaction, compression, rolling, tamping, reaming, etc. The method most

commonly used in concrete factories is vibrocompaction, for which fixed platform vibrators, table vibrators, or internal vibrators are used. During consolidation on a platform vibrator (the most commonly used technique) the form is installed on the platform and the concrete mix is readily consolidated by means of vibrations created by a special machine.

Hydrothermal treatment. In order to speed up hardening of the concrete, newly formed elements are subjected to hydrothermal treatment. The following types of such treatment are commonly used: steam curing at standard pressure and a temperature between 70 and 100°C; contact heating at a temperature about 100°C; steaming in an autoclave at a temperature between 174 and 190°C and a pressure of 8 to 12 atm (gauge); and electrical heating. Steam curing at low (normal) pressure in continuous or periodic action chambers is the technique most commonly used.

Continuous action chambers are tunnels into which the formed elements are continuously pushed on trolleys at one end and already hardened elements are withdrawn at the other. During their movement through the chamber the elements pass through zones of preheating, isothermic heating, and cooling, each of which is kept at the required temperature and humidity. The concrete members thus get roughly 70% of the 28-day hardness in 8 to 14 hours.

In periodic chambers, the formed members are loaded by crane into the chamber in the forms or on pallets in several rows. The chamber is closed, and steam then admitted through pipes with apertures. The temperature in the chamber is gradually raised to the maximum, and the members heated throughout their thickness. After a period of exothermic curing the items are gradually cooled. The length of the steam-curing process is 12 to 16 hours.

Techniques for making reinforced concrete members. In modern plants the following production methods for precast reinforced concrete members are used: casting-bed, stage-by-stage, line production, cassette, and continuous vibrorolling.

With the *casting-bed technique* the members are fabricated in fixed forms (on a bed), while special machines move from station to station, each carrying out specific operation.

Flat beds or moulds are used to fabricate members by this method. The formed elements are hardened where they are formed. To accelerate hardening pipes are laid in the

bed or mould with a continuous flow of hot water or steam.

This method is used, as a rule, for large-size elements for industrial and other types of construction. It is usually used in concrete-casting yards, and seldom in factories.

With the *stage-by-stage method* the formed elements are moved in a steady flow from one station to another. Each station has equipment adapted to the character of the work, sets of machinery that in most cases perform separate groups of technological operations. Normally there are stations for dismantling, preparation of forms, laying and tensioning of reinforcement, forming of the element, accelerated hardening of the concrete, quality control, and finishing of the product. This technique makes it possible to make a wide range of reinforced concrete members, and to adjust the equipment for the change from one type of member to another.

With the *line production* the formed members are moved on form-trolleys along the process line at a given pace. With this method there is maximum breaking down of the production process into separate operations, each of which is performed at a separate station. In deciding the number of stations and choosing the process equipment, the aim is to ensure that the length of time for the operations at each station is as far as possible the same.

When the range of type sizes is limited and output of members is on a mass-scale, the line production ensures high productivity and low cost.

The cassette method is a qualitatively new type of casting technology, based on vertical forming of elements in a fixed cassette setup consisting of several vertical metallic forms (compartments). The reinforcement is put into each compartment, after which it is filled with concrete mix. The mix is consolidated by external or internal vibrators. Contact heating through the walls of compartments is used to cure the members (by steam at a temperature around 100°C). On completion of the heat treatment the walls of the compartment of the cassette setup are opened by means of hydraulic jacks and the element withdrawn by an overhead travelling crane and taken to the cooling station or the storage yard.

The cassette method is used to fabricate internal load-bearing wall panels, floor panels, staircases, and stair landings, balcony slabs, and other reinforced concrete elements.

The special feature of the *continuous vibration method* is that the whole process of fabrication of elements, from preparation of the concrete mix to final output of finished members, is carried out on a continuous-action plant. The plant consists of a main unit, the vibrating-roller mill, a batching section, a screw-mixer, a continuous-action concrete mixer, a passing roller table, a filter, and a number of auxiliary mechanisms.

The vibrorolling mill is a moving conveyor consisting of a forming belt, tensioning station, a drive, a forming and calibrating sections, and a heat treatment section where hardening is accelerated by contact heating.

The vibrorolling technique is used now to fabricate flat reinforced concrete floor slabs, panels for partitions between rooms, and load-bearing walls between apartments of room size, expanded-clay concrete load-bearing walls for large-panel blocks of flats, corrugated thin-walled shells for roofing housing and industrial buildings.

The quality of reinforced concrete elements is controlled by inspectors of the factory's quality control department.

Quality control includes checking of the appearance of members, their shape and size, thickness of the protective layer, position of the reinforcement and embedded fittings, the strength of the concrete actually produced and the corresponding specification, and also, where necessary, determination of the density of the concrete (for cladding members). Control samples taken from each batch of members are tested for strength, rigidity, and cracking resistance.

9.6. Transporting and Storing of Reinforced Concrete Members

Precast reinforced concrete members are usually transported from the fabricating factory to the building site by road transport. Elements of low weight and small size (slabs, blocks, staircases and landings) are carried in lorries; large and heavy elements (e.g. columns) are carried on trailers; wall panels on articulated panel carriers.

Before members are off-loaded from the lorries a representative of the building organization accepts them, having checked the outward appearance of their state, the relevant certificate attached to the delivery note, and the stamp of the factory's quality inspector. During off-loading every

big member (load-bearing elements and details) is checked for cracking, bending or warping, and other defects.

Elements are stacked in the site yard in such a way that the factory stamp can be easily read from the passages between them and the lifting eyes are at the top.

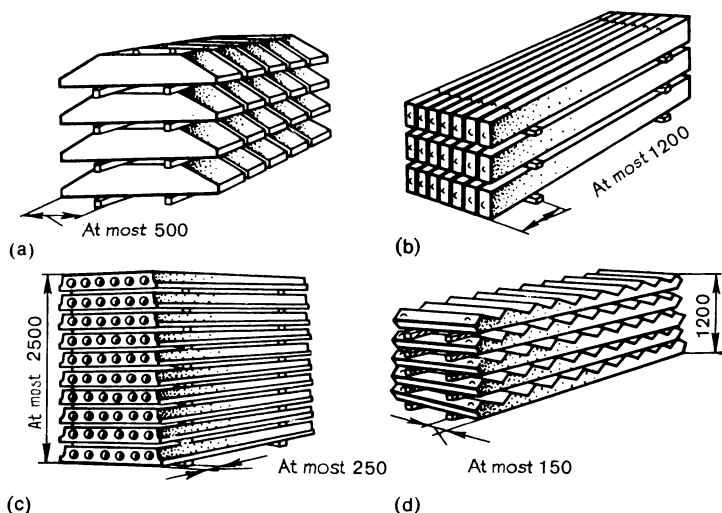


Fig. 40. Stacking of precast reinforced concrete members
(a) foundation blocks; (b) collar- or tie-beams; (c) multicavity flooring slabs;
(d) flights of steps for stairs

The position of elements in the stack (with the exception of columns, posts) and the supports for them during storage should reproduce the conditions of their work in the structure, without causing overstress in the concrete, or damaging them. In specifying the height of the stack, lifting arrangements, the recommendations of the standards and technical specification for the type of element are followed.

When stacking the elements the lowest row is laid on wooden blocks 100 mm square, and the succeeding rows on beams or planks of 40×60 mm or 40×100 mm in section.

The panels of load-bearing and interior walls are transported in a vertical position and stored in special metal magazines or pyramids resting on supports in a vertical or leaning position. The flat floor slabs are transported in an inclined position (at an angle of 8° to 12° from the vertical).

The safety rules must be strictly observed during carriage and stacking of reinforced concrete elements (Fig. 40).

Chapter X

Artificial Stone Materials and Products Made with Mineral Binders

Artificial stone materials and products made with mineral binders are now used extensively by the construction industry. Cementing matters that have the property of hardening impart necessary strength to these materials and products which, depending on the kind of binder used, are divided into: (1) lime-based, (2) gypsum-based, (3) cement-asbestos-based, and (4) magnesia-based materials and products.

10.1. Silica Materials and Products

Silica products rank first among artificial materials and products made with mineral binders. They are manufactured from a mixture of lime or other lime-based binders, finely dispersed siliceous additions, sand, and water by molding and subsequent autoclave treatment.

Silica (lime-and-sand) brick and articles made from lime concrete find wide use in the construction of residential, civil, and industrial buildings.

Silica brick is an artificial stone, the brick being pressed from a mixture of a binder and sand, and steamed in autoclaves. Materials used in the manufacture of silica brick are air-hardening lime (6-8% calculated for CaO), quartz sand (92-94% of the dry mix mass), and water (7-8% of the dry mix used for slacking the lime and imparting necessary moisture content to the mass).

Silica bricks may be single ($250 \times 120 \times 65$ mm) and modular ($250 \times 120 \times 88$ mm). The former are manufactured both as solid and hollow bricks; the latter only as hollow, their mass (in the dried to a constant mass state) being no more than 4.3 kg.

The voids in hollow silica brick are perpendicular to the brick bed; they may be blind or through.

The bricks are generally of light-grey color which may be changed by adding alkali-resistant mineral pigments.

A high pressure under which bricks are formed gives them an exact size, the density of the brick being higher than of common brick—1 800-1 900 kg/m³. Depending on the ultimate compressive and bending strength, silica bricks are assigned 6 grades: Grade 75, Grade 100, Grade 125, Grade 150, Grade 200, and Grade 250. Frost resistance of silica brick is 15-50 cycles, water-absorption ranges from 18 to 14% (by mass).

Like clay burnt brick, silica brick is used for construction of buildings and structures (carrying walls, columns, etc.) and is not used for laying foundations and walls in very humid conditions, as underground and drain waters destroy the bricks. They are not to be used in high-temperature structures, for instance, furnaces and chimneys.

Autoclave-hardened lime concrete products are manufactured using lime-sand, lime-ash, and other lime binders.

By texture, lime concretes may be dense, fine-grained, the aggregates for which are quartz and quartz-feldspar sands, and cellular concrete.

The density of the products made from dense lime concrete is 1 800-2 200 kg/m³. The compressive strength of lime concrete varies from 10 to 60 MPa and depends on the concrete mix composition, autoclave treatment conditions, and several other factors. Lime concrete exhibits satisfactory water resistance; in case of complete water saturation the decrease in strength is no more than 25%, frost resistance being 25-50 cycles.

Large building blocks of exterior walls with slot cavities, building blocks of interior load-bearing walls, panels, floors, and load-bearing partitions, columns, beams, stair wells, staircases and flights, foundation and socle blocks, architectural blocks, and other reinforced products are made from dense lime concrete.

The density of products made from cellular lime concrete ranges between 300 and 1 200 kg/m³, and strength varies from 10 to 20 MPa; their coefficient of heat conductivity is 0.093-0.46 W/(m°C).

Cellular lime concrete is used in the manufacture of reinforced roofing structures of industrial buildings, interfloors and mansard roofs of residential buildings, reinforced large-size products for exterior and interior walls and also for making heat-insulating slabs.

10.2. Gypsum and Gypsum-Concrete Products

Gypsum products are made from gypsum paste. The properties of gypsum products can be improved by adding small amounts (10-25% of the gypsum mass) of finely ground mineral or organic fillers to the gypsum paste.

Gypsum products are made from concrete mix, using a gypsum binder and porous aggregates—mineral (cinder, slags, shell rock and others) and organic (sawdust, chopped straw, reed, etc.).

Gypsum and gypsum-concrete products of a comparatively low density have a sufficiently high strength, low coefficient of heat conductivity, and high soundproofing properties. Besides, they lend themselves to machining favourably and are readily coloured. Unfortunately, they exhibit a low water resistance.

A wide variety of gypsum and gypsum-concrete products are used in the present-day construction industry. Among them are gypsum wallboard, partition slabs, partition panels, floor panels, etc.

Gypsum wallboard is a sheet of finishing material made up of constructional gypsum with or without mineral or organic admixtures in the form of gypsum core covered on both sides with board and firmly glued to it.

Gypsum wallboards are usually 1.2 m wide, from 2.5 to 3.3 m long, and vary in thickness from 8 to 10 mm. They have a low density, heat-, fire- and soundproof, and can be easily cut. Gypsum wallboards are utilized for interior finishing of masonry and wooden walls, partition walls and ceilings of rooms where relative humidity of air is up to 60%. Sheets are fixed to the surface with gypsum-glue, foam-gypsum, and other mastics (Fig. 41).

Partition gypsum plates are manufactured as hollow (with through voids) and solid (900 × 300 × 80 mm).



Fig. 41. Facing a wall with gypsum plaster board

The mechanical properties of gypsum products are determined by their compressive strength equal to 3.5 MPa and a bending tensile strength of 1.7 MPa, the bulk density being between 900 and 1 400 kg/m³. During transportation and storage care must be taken to safeguard these products against moisture.

Partition plates are used for load-bearing partition walls in civil and industrial buildings, if moisture is not the contending factor.

Gypsum-concrete partition panels are manufactured of the room length, or of a part of it, and the width equal to the floor height; the panels are usually 80-100 mm thick. They can be either continuous or with door openings. Their bending strength is increased by reinforcing them with wood laths.

Panels are manufactured in vibrorolling mills as follows: wood-lath frames filled with gypsum-concrete mass are placed on the lower mobile belt of the mill; the mix is compacted by rollers and hardens as it moves along the mill and attains some strength necessary for the panel to be transferred to the kiln where it is dried to 8% humidity and attains a compressive strength of no less than 3.5 MPa.

Panels are transported to the construction site in special trucks. At the site the panels are kept until erection on pole plates in metallic cassettes and covered with tarpaulin or sheets to protect against exposure to precipitation.

Floor panels are manufactured from gypsum-concrete using gypsum-puzzolana cement binders and are reinforced with timber frames. They are generally 50-60 mm thick, 3-6 m long, and 2-7 m wide. The water content, after the panels leave the kiln, must not exceed 10%, the compressive strength of gypsum concrete being no less than 7 MPa.

The density of gypsum concrete floor panels must not exceed 1 300 kg/m³. Their surface should be ready for accepting floor coverings, tiles, or mastic materials.

Bathrooms, kitchens, ventilation services in residential buildings, and ground floor exterior walls are various places where these panels are used.

10.3. Asbestos-Cement Products

Asbestos-cement products are molded from a mix of asbestos, portland cement, and water.

Natural asbestos has a fibrous structure and readily splits into finest and strong fibres which act as dispersed

reinforcements imparting high bending strength to the asbestos-cement products. The molded products are given hygrothermal treatment in steam curing chambers or in autoclaves.

Asbestos-cement products exhibit a high strength and are frost-resistant. They are stable to heat, have a low coefficient of heat conductivity, and comparatively readily lend themselves to machining. They do not corrode in water, with time their strength slightly increases. Asbestos-cement products can be coloured into various shades by adding pigments into the starting mix.

A variety of asbestos-cement products are used by the construction industry. Among them are flat facing plates, large-size sheets, corrugated sheets, warmth-keeping plates, tubes, ducts.

Flat facing plates are used for interior and exterior facing of walls and partitions. They are usually 600-1 600 mm long, 300-1 200 mm wide, and 4-10 mm thick. Their compressive strength varies between 16 and 25 MPa, and the density ranges from 1 600 to 1 750 kg/m³.

The facing plates may be coloured or glazed. Plates covered with water resistant enamels are used for facing panels, ceilings, walls of bathrooms, toilets, and kitchens in residential and public buildings.

Large-size flat sheets are used for making bathroom and kitchen panels, for facing exterior wall panels, air pits, and other vertical fencing structures.

Asbestos-cement corrugated sheets, depending on their sizes and utility, are divided into:

corrugated sheets of usual profile. Such sheets are used in making roofs of residential and public buildings. The size of a sheet is usually 1 200 mm long, 678 mm wide, and 5.5 mm thick, the corrugation height being 28 mm;

fluted sheets of high rigidity profile. They are employed in making roof coverings and walls of industrial buildings and structures.

Warmth-keeping asbestos-cement plates are made up of two asbestos-cement sheets with warmth-keeping lagging between them. Such plates are intended for roofings of industrial buildings. A 50 mm thick layer of mineral wool is used as warmth-keeping lagging.

Asbestos-cement pipes, according to their use, are divided into pressure, non-pressure water pipes, gas pipes, and casing pipes.

Pressure water pipes are used to supply water at pressures from 0.3 to 1.2 MPa. They are usually 3 400 mm long and their diameter varies from 50 to 500 mm.

Non-pressure water pipes are used for plumbing, sewers, and drains. Their diameter ranges between 100 and 600 mm, and length from 2 950 mm to 3 950 mm.

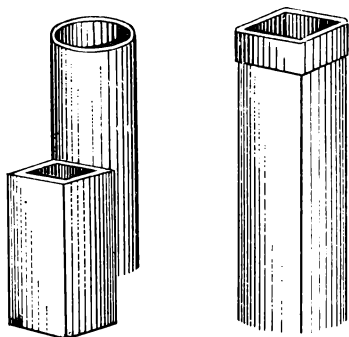


Fig. 42. Asbestos-cement ventilation ducts

Underground gas-supply pipes are intended to carry gas at pressures up to 0.3 MPa. Usually they are about 6 000 mm long and their diameter varies from 100 to 500 mm.

Casing tubes are used to fasten boreholes for water at depths up to 200 m, with working pressure up to 1.2 MPa. They are usually 3 950 mm long and from 200 to 500 mm in diameter.

Tubing couplings with rubber rings are used to join water-supply pipes and should therefore be watertight.

Special-purpose asbestos-cement products, depending on their design and application, are manufactured in the form of rectangular ducts, semi-cylinders, various parts and structures.

Ducts (Fig. 42) are used in laying air conduits of ventilation and air-conditioning systems in production areas and amenity rooms of industrial buildings.

Various architectural parts, window and door casings, jambs, registers, etc. are also made from asbestos cement.

10.4. Products Made with Magnesia Cement

Magnesia cements or Sorel cements (caustic magnesite or dolomite) mixed with magnesium chloride solution firmly join with organic aggregates and protect them against putrefaction. Thanks to this property, magnesia cements are used for making xylolite and fibrolite.

Xylolite is obtained upon solidification of the mixture of sawdust and magnesia cement mixed with magnesium chloride solution. Additions like tripoli, asbestos, quartz sand, and pigments are also used. The density of xylolite

is between 1 000 and 1 200 kg/m³, compressive strength from 30 to 40 MPa, and the coefficient of heat conductivity is about 0.28 W/(m°C). It is used for making jointless floors and xylolite tiles.

Jointless floors are made from a xylolite mix of plastic consistency. The mix prepared at site is put on the foundation, levelled, and compacted by vibration. Xylolite floors are warmth-keeping and soundproof coverings which are smooth and offer good resistance to attrition and dynamic loads. Low water resistance is the main disadvantage of such floors. Therefore they are usually laid in administrative buildings, hospitals, clubs, cinemas, and certain industrial buildings.

Square or hexagonal tiles for floors and window sills, and other products are molded from xylolite. Their surface is coloured and imparted marble, malachite, etc. finish.

Fibrolite is a heat-insulating material usually marketed in the form of plates. The plates are made from sawdust containing magnesia cement. Fibrolite plates, depending on their density, are used to provide insulation of walls and floors or for filling walls, ceilings, and partitions of framed buildings. Properties and the fields of application of fibrolite are discussed in detail in Chapter XIII.

Chapter XI

Wood and Wood Materials

11.1. Wood

As a construction material, wood is extremely important. Its wide application in the construction industry may be attributed to many of its useful properties, for instance, high strength, low density, low thermal conductivity, and easy machining. It does not exhibit, however, similar properties in different directions, readily decays and easily burns, is hygroscopic, and has other defects.

Wood is used in the manufacture of structural elements, heat-insulating and finishing materials, furniture, pulp, paper, rosins, and various chemical products. Ever-growing demand of wood calls for its economic and rational use.

Fibrolite, wood-fibre and wood-particle boards, and other products are produced from wood wastes—sawdust, shavings, chips, and half logs.

Woods used by the construction industry are subdivided into round timber and lumber.

Round timbers are trunks of nominal dimensions which are debarked and freed from boughs. Depending on the diameter in the upper face, round timbers are subdivided into logs, rickers, and thin poles.

Logs have a diameter no less than 14 cm in the upper face, their length varies between 4 and 6.5 m. Softwood

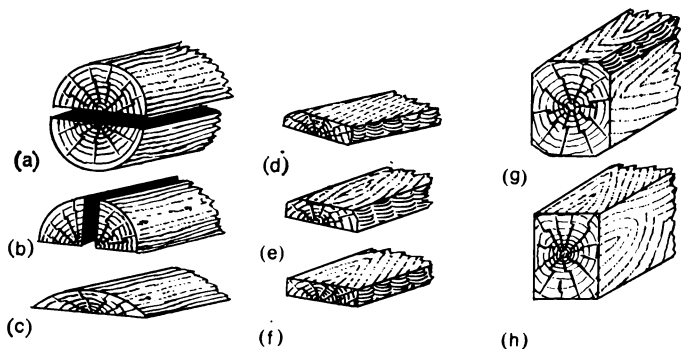


Fig. 43. Kinds of lumbers

(a) slabs; (b) quartered logs; (c) half-logs; (d) untrimmed board; (e) half-trimmed board; (f) trimmed board; (g) square; (h) clean trimmed cant

logs are used in bearing structures of civil and industrial buildings, and hydraulic structures, and also as piles and frameworks of timber bridges.

Rickers are in the diameter of 8-13 cm in the upper face and 3 to 9 m long.

Poles have a diameter of 3-7 cm in the upper face and they are from 3 to 9 m long.

Lumber or sawn timbers are obtained by length cutting of logs. By their cross section, lumbers are divided into slabs, quartered logs, half logs, boards (planks), cants, and bars (Fig. 43).

Slabs are obtained by length cutting of logs into two parts. Quartered logs are made by cutting along two mutually perpendicular diameters. Half-log is the exterior cut part of a log one side of which is saw cut through its length and the other is unsawn.

Boards are produced by length cutting along several parallel planes. They are usually 13-100 mm thick and 80-250 mm wide. Softwood boards are produced in lengths about 6.5 m; hardwood boards are made in lengths about 5 m.

Bars are about 100 mm thick, their width to thickness ratio is less than 2. Often they have square cross section.

Cants are more than 100 mm thick and wide.

Lumber is generally transported on flat-cars and stored in piles. Two-row wood roof is provided to cover lumber piles kept in the open.

Timber is air-dried or kiln-dried and treated with antiseptics to increase its guaranteed life period; it may be creosoted or chemically treated to protect against decay.

11.2. Products Made from Wood

A wide variety of products is made from hard and soft wood. Among them are long surfaced products, products for parquet floors, laminated wood, plywood, etc.

Long surfaced products include floor boards, matched boards having a groove on one edge and a ridge (protrusion) on the other which ensures joining of boards when

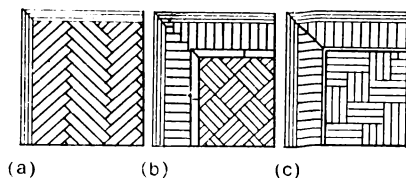


Fig. 44. Block parquetry floor patterns

(a) without frieze; (b) with frieze and strap; (c) with frieze and vein

laying floors and also in planking walls and floors. With these products are grouped lengthly profiled products, for example, plinths, mouldings, handrails, door and window casings, and others.

Parquet floors are divided into block parquetry (Fig. 44), glued-laminated parquetry, parquet panelling, and parquet planks.

Members and structures made from wood, which are manufactured as beams, arches, trusses, piles, panel forms,

etc., are finding wide application in industrial construction.

Glued structures are made from small-size wood materials and members pasted together with phenol formaldehyde glues. The structures obtained are more durable than ordinary ones, because the anisotropic properties of wood are accounted for in their making and the glue interlayer makes the structure monolithic.

Chapter XII

Asphalt and Tar Cements and Materials Made from Them

12.1. Asphalt and Tar Cements

Asphalt and tar cements are organic binders constituted by high-molecular compounds. Their main characteristics are that they soften when heated and harden when cooled.

Organic binders are divided into asphalts and tars.

Asphalt cements, depending on the type of raw material used, are subdivided into natural and oil asphalts.

Rock asphalts are dark-brown to black organic substances; they are practically odourless and exhibit the property of ductility when heated. Natural asphalts are rarely found in the pure form. Often they are contained in rocks, mainly limestone and shell rock.

Rocks containing 5 to 20% natural asphalt are known as *asphalt rocks*. Bituminous (asphalt) varnishes are prepared from natural asphalt; asphaltic mortar and concrete are prepared from asphalt rock powder.

Oil or petroleum asphalts are obtained in refining petroleum and its resinous residues. Depending on viscosity, oil asphalts can be solid, semisolid, and liquid. Liquid asphalts are produced by diluting solid or semisolid asphalts with liquid petroleum products. The quality of asphalts is characterized not only by their viscosity, but also by their softening point and the stretchability. By these three properties, asphalts are assigned various grades. Solid and semisolid asphalts are classed into constructional and roofing asphalts.

Oil asphalts are waterproof, resistant to acids, alkalies, corrosive liquids and vapours, firmly adhere to wood, metal, and stone materials. Their main disadvantage is that with time they grow harder and more brittle, that is, they age under the action of sunlight and the oxygen of air.

Asphalt mortars and concretes, roll and waterproof roofing are made from solid and semisolid oil asphalts. Liquid asphalt is used only for laying pavements.

Tar cements are prepared from coal or oil shales. Coal tar (liquid) and pitch (solid) are used in the construction industry. Mixtures of coal tar and pitch, and also of pitch and anthracene oil have excellent adhesive properties. Mineral additions, for instance finely ground limestone or dolomite, are added to a sand and coal tar mixture to raise its viscosity and resistance to atmospheric action. Tar cements are used in constructing roads and making roofing felt.

12.2. Asphalt and Tar Mortars and Concretes

Mortars and cements are prepared with organic binders (asphalt, bitumen, or tar) and named according to the binder used.

Asphalt mortar is made up of binders (asphalt, bitumen, or tar), finely ground rocks, and sand. The binder accounts for 9-11 % of the mix. The components are mixed in special pans at a temperature of 160-180°C.

Asphalt mortar is widely used by the construction industry for water proofing, laying asphalt floors in industrial buildings, as an underlayment below floors in domestic and civic buildings, and in pavements. Freshly laid hot asphalt mortar is compacted with rollers. On cooling the mortar hardens.

Asphalt concrete consists of an organic binder, mineral powder, sand, and coarse aggregate (broken stone or gravel). The bitumen content by mass is 5-6%. The quality of asphalt concrete depends on the kind of binder used, the amount of fine grain mineral admixture, and the quality of coarse aggregate. Asphalt concretes can be hot or cold. Hot asphalt concretes are prepared in special mixers where they are heated to 180-200°C, transported to the construction site in dump trucks, hot laid, and compacted with self-propelled rollers. As the binder cools, the concrete hardens. Cold asphalt mixes are prepared with liquid bitumens and tars, and laid in the cold state. They take several days to

solidify as a result of oxidation and evaporation of thinners.

Asphalt concrete is mainly used in road construction and also for laying floors in industrial shops, warehouses, and stores.

Tar mortar and concretes are analogous to asphalt ones. A mixture of coal tar or pitch and a mineral powder is used as a binder. Tar mortar and concretes exhibit, as compared with asphalt mortar and concrete, a lower water resistance, lower wear resistance, lower thermal stability, and durability. This is the reason why they are rarely used in the construction industry.

Tar concretes are employed for making pavements in minor and local roads.

12.3. Roofing and Hydraulic-Insulating Materials

Different roofing and hydraulic-insulating materials in the form of mastics, pastes, roll pasting and sealing materials are widely used for protection of buildings or their structural elements against the action of precipitation or underground waters.

Mastic roofing and hydraulic-insulating materials are mixes of organic binders, mineral aggregates, and additions. Depending on the binder used, mastics can be bituminous, bitumen-rubber, tar, and others.

Hot bituminous mastic is a homogeneous mass consisting of a bitumen binder and aggregate. It is prepared by heating bitumens to 180-200°C with subsequent addition of 15-30% aggregate to the melted mass.

Cold bituminous mastics contain oil bitumen, organic solvent (straw oil, kerosine), aggregate, plasticizer, and antiseptic. At $18 \pm 2^\circ\text{C}$ cold mastics must be fluid, and homogeneous.

Bitumen-rubber insulation mastic is a homogeneous mixture of roofing bitumens and fine rubber crumb obtained from used automobile tires. It is resilient, flexible, and frost resistant. Used for damp proofing of the basements in domestic buildings and in pasting rolls for making multiply roofings.

Tar mastics are prepared by mixing tar binder (melt of coal-tar pitches and anthracene oil) and aggregates. Ulot

tar mastics are employed for pasting rolled tar materials in hydraulic insulation and roofing jobs.

Roll roofing and hydraulic-insulating materials. Ruberoid, fibre-glass-backed ruberoid, built-up ruberoid, pergamyn (asphalt felt), hydroizol, izol, foilizol, tar paper, and other materials are now widely used as roll roofing and hydraulic-insulating materials.

Ruberoid (roofing felt) is prepared from oil-roofing-bitumen impregnated board. Its both sides are coated with high-melting oil bitumens and covered with a thin layer of finely ground talcum or other mineral powder (use can also be made of coarse or mica grit for the purpose).

Ruberoid is used for protecting underground portions of buildings and structures against penetration of water, and for making the top layer of sloping and flat roofs of domestic and industrial buildings. The lower layers of roofings are made from lining ruberoid coated with fine-grain grit.

Fibre-glass-backed ruberoid is a roofing and hydraulic-insulating material prepared by applying a bitumen binder on both sides of the fibre-glass cloth. It is employed for hydraulic insulation of upper and lower layers of the roofing mat.

Built-up ruberoid is a new type of roofing material heavily coated with bitumen. When making a roofing, the surface of the built-up ruberoid is heated; the bitumen layer melts and ruberoid sticks on to the surface.

Hydroizol is a gritless bioresistant hydraulic-insulating roofing prepared by impregnating asbestos paper with oil bitumens. It is highly water resistant, does not decay, and has a long life; it is grouped with combustible materials.

Hydroizol is used for hydraulic insulation of underground and other structures, and as anticorrosive coating for pipelines.

Izol is an elastic material produced from a mix of bitumen-rubber binder, aggregate, plasticizer, and antiseptic.

It is very durable, practically does not absorb water, and remains flexible even at subzero temperatures. Roll izol is used as hydraulic-insulating material in foundations and other structures where shrinkage and deformation occur. Like hydroizol, it is pasted on to bitumen-rubber mastics.

Foilizol is a roofing composed of thin fluted foil, the lower surface of which is coated with a rubber-bitumen

mastic or polymer-bitumen binder. It exhibits an excellent breaking strength flexibility, and durability. It is employed in making the hydraulic insulation layer of underground structures and also the upper roll mat of roofing.

Metalizol is composed of aluminium foil coated with oil bitumen on both sides. Exhibits an excellent breaking strength, good flexibility, and durability. Finds application in damp proofing of underground structures.

Glass-fibre-backed izol roofing is prepared by applying rubber-bitumen mass on both sides of the fibreglass cloth, and giving a coating of grit. It is employed for damp proofing of critical members and structures.

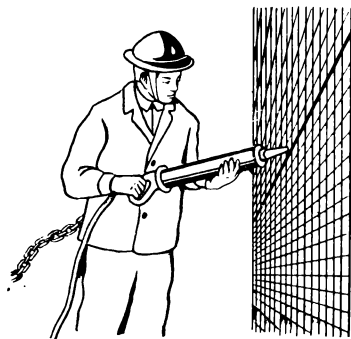


Fig. 45. Applying thiokol sealing compound by pneumatic gun

ings. Tarred felt is used as lining; it is obtained by impregnating board with tar without protective grit covering.

Roll hydraulic-insulating materials are stored in closed unheated rooms or sheds in vertical position in no more than two rows in height.

Sealing materials are prepared as mastics, vulcanizing pastes, resilient linings, and shaped products. They are used to seal joints of exterior wall panels and also as air-, heat-, water-, and sound-proofing materials.

Polyisobutyl mastic (Grade YMC-50) is a sealing compound which does not harden. It adheres well to masonry, stone, and metal. Forms a compact impermeable layer in joints of prefabricated constructions, offers a good resistance to atmospheric effects and is absolutely air- and watertight. It is employed for sealing vertical and horizontal joints of large-panel buildings and places adjoining to panels of window and door casings. Also used for sealing gaps around the edges of interior walls and partitions.

Thiokol sealing mastic is prepared at site by thoroughly mixing liquid thiokol, vulcanizing paste, and a thinner. The mastic readily vulcanizes and changes into a rubber-like mass.

Thiokol sealers are flexible, adhere well to masonry, and are air- and watertight. They are used to seal joints between the panels of exterior walls and in junctions between panels of interior walls and partitions (Fig. 45).

Gernit is a flexible sealing pad with a length between 2.5 and 3.2 m and diameter from 40 mm to 60 mm. It is prepared by curing a gas-expanded rubber mixture. The compact watertight film (exterior) formed on the surface of pads protects the porous material against water saturation. Gernit is used for filling joints between panels; in the joints the pads get squeezed to 30-40% of their initial volume.

Poroizol is a porous flexible caulking material which is prepared as braided straps of circular, oval or rectangular cross section with 30, 40, 50, and 60 mm diameter (side). For quality caulking of joints of exterior wall panels, the poroizol in the joint must be squeezed to 30-50% of the initial cross-sectional size and should be pasted with izol mastic on to the mating surfaces.

Chapter XIII

Heat-Insulating Materials

13.1. Kinds and Properties

Materials used for protection of heated domestic, public, industrial, and agricultural buildings, as well as heat-generating units and pipelines against heat losses or for safeguarding various chambers and coolers against overheating are called the heat-insulating materials. Their bulk density is no more than 700 kg/m^3 . They have a low coefficient of heat conductivity [thermal transmittance no more than $0.175 \text{ W/(m}^\circ\text{C)}$] and are very porous.

Heat-insulating materials are classified according to their appearance, texture, the kind of raw material, density, stiffness (relative compressive strain), thermal conductivity, and inflammability.

By texture and appearance, they may be slabs, bricks, blocks, cylinders, semicylinders, segments, rolls, mats, cords, braided straps, mineral wool, glass wool, expanded perlite, and vermiculite.

Heat-insulating materials can be inorganic and organic. The former are prepared from varied mineral raw materials (rocks, slags, glass, asbestos) and the latter from the waste materials obtained in processing wood, reed, straw, peat, etc., and also from synthetic polymers.

By their density (in kg/m^3) in the dry state, heat-insulating materials are assigned the following grades: 15, 25, 35, 56, 75, 100, 125, 150, 175, 200, 225, 250, 300, 350, 400, 500, and 600.

Thermal conductivity is the most important property of heat-insulating materials. Their coefficient of thermal conductivity is 0.04-0.175 $\text{W}/(\text{m}^\circ\text{C})$.

Specific requirements are placed upon the quality of heat-insulating materials. Their mechanical strength must be enough for safe storage, transportation, and erection. They should be bioresistant and dry (with low hygroscopicity); with an increase in moisture content, their coefficient of heat conductivity rises appreciably. Besides, they should be chemical-resistant and fire-proof.

13.2. Inorganic Heat-Insulating Materials

They cover mineral wool, glass fibre, foamglass, cellular concrete, expanded perlite and vermiculite, asbestos-containing materials, etc.

Mineral wool (Fig. 46) is a fibrous material obtained from silicate melt of rocks and blast-furnace slags or their mixtures. Depending on bulk density, mineral wool is assigned three grades: 75, 100, and 125. It is fire-proof, does not decay, and is low-hygroscopic. Its coefficient of heat conductivity varies from 0.044 to 0.052 $\text{W}/(\text{m}^\circ\text{C})$.

Mineral wool is used in making such products as felt, stiff and semistiff slabs, shells, segments.

Slabs and mats manufactured from mineral wool with a plastic binder are used to provide thermal insulation of buildings, industrial equipment, and pipelines at surface temperatures between -60 and $+400^\circ\text{C}$. The slabs are usually square or rectangular, 1 000 mm long, 500 and 1 000 mm wide, and 40, 50, and 60 mm thick. Mats are

manufactured in rolls 2 000, 3 000, and 4 000 mm long, 500 and 1 000 mm wide, and 70, 80, 90, and 100 mm thick. Depending on the density, slabs and mats are assigned the following grades: 50, 75, 100, 125, and 150. Their coefficient of heat conductivity is between 0.040 and 0.051 W/(m°C).

Slabs wrapped up in greese-proof or other type of impermeable paper are transported to the site in cardboard cases. During transportation and storage care must be taken to safeguard the slabs against damage and moisture.

Stiff heat-insulation slabs from mineral wool with bitumen binder are prepared by mixing mineral wool and bitumen emulsion with subsequent molding and drying. Slabs are usually 1 000 mm long, 500 mm wide, and 40, 50, 60, and 70 mm thick. According to bulk density, the stiff slabs are assigned three grades: 200, 250, and 300. The coefficient of heat conductivity depends on the grade and varies from 0.058 to 0.081 W/(m°C).

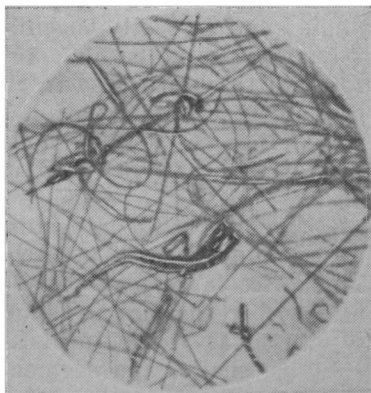


Fig. 46. Mineral wool viewed through a microscope

Slabs are used to provide insulation of structural members, production equipment and pipelines, and industrial cold-storage plants, the temperature of the surfaces to be insulated being between -100 and $+70^{\circ}\text{C}$.

Glass wool is a material made up of haphazardly arranged glass fibres obtained from molten glass. The bulk density of glass wool ranges between 75 and 125 kg/m³ and the coefficient of heat conductivity from 0.04 to 0.05 W/(m°C). Mats, slabs, shells, and woven materials are made from glass wool.

Mats made from glass staple are widely used for heat insulation of plane and cylindrical surfaces whose temperature does not exceed 180°C .

Semistiff slabs are prepared with synthetic resin binders, one side pasted with glass cloth or without it.

Foam glass is a material having a cellular structure. Finely ground glass mixed with a foaming agent (milled limestone) which upon melting expands and on cooling changes into a solid material of cellular structure.

Foam glass exhibits several valuable properties which distinguish it from many other heat-insulating materials. Its porosity is 80-95%, pore (cell) size varies from 0.1 to 3 mm, and bulk density ranges between 200-600 kg/m³. It has the property of low moisture absorption; also exhibits water- and frost-resisting properties. It is fireproof, absorbs sound, and is easily machined.

Foam glass slabs 500 mm long, 400 mm wide, and 70-140 mm thick are used in civic and industrial buildings to provide thermal insulation of walls, partitions, roofs, etc. Semicylinders, shells, and segments are employed for insulating heat-generating units and district heating pipelines.

Cellular concrete is a stone material made up of a solidified binder with uniformly distributed closed pores. Thanks to large porosity (70-85%), cellular concrete exhibits a low thermal conductivity. This is the reason why it is used as a heat-insulating material.

Slabs, shells, and segments made from cellular concrete are used for thermal insulation of pipelines. Their density in the dry state varies from 350 to 400 kg/m³. They are employed to provide insulation of thermal losses from surfaces at about 400°C.

Perlite and perlite heat-insulating products. Perlite is a glass-like material of volcanic origin. Under heat treatment (about 1 000°C) perlite is expanded to about 20 times its original volume. Expanded perlite is a porous lightweight heat-resistant material. It is used as sand or broken stone, and with various binders for making heat-insulating products.

The bulk density of perlite in the form of sand varies from 75 to 250 kg/m³, in the form of broken stone 5-20 mm in size 300 and 600 kg/m³. Portland cement, plastic clays, soluble glass, oil bitumen, synthetic resins, etc. can be used as binders for perlite. The density of the products (slabs, semicylinders, segments, etc.) varies from 250 to 450 kg/m³ and their coefficient of heat conductivity between 0.05 and 0.18 W/(m°C).

Depending on the temperature stability of the binders employed, the expanded perlite products are used for va-

rious purposes. For instance, products made with cement binder or soluble glass are employed to provide thermal insulation of furnaces, boilers, pipelines, etc; products with organic binders (bitumens, synthetic resins, etc.) are employed as insulating materials in the construction industry and cold storages.

Vermiculite and vermiculite-containing heat-insulating products. Expanded vermiculite is a highly porous material available in the form of golden flakes. Under heat treatment, the natural vermiculite is expanded to about 20 times or more its original volume.

Expanded vermiculite is highly porous, has a low coefficient of heat conductivity. In the form of 1-10 mm grains

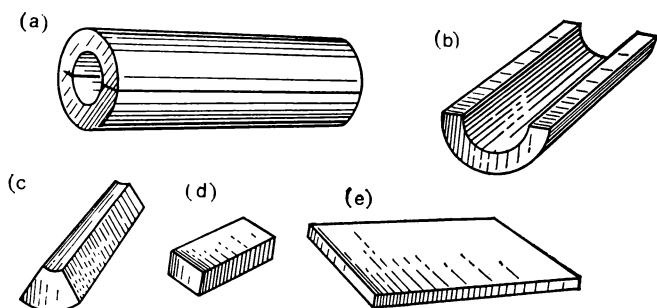


Fig. 47. Heat-insulating articles

(a) cylinder; (b) semicylinder (shell); (c) segment; (d) brick; (e) plate

it is used as a covering of surfaces with a temperature up to 1100°C , and also for making molded products; the density varies from 100 to 200 kg/m^3 .

In making heat-insulating products, cement, gypsum, plastic clay, bitumen, soluble glass, synthetic resins are used as binders. Fibrous materials, for instance, asbestos, glass fibre, are employed as additives.

The density of products made from expanded vermiculite (slabs, semicylinders, segments, etc.) (Fig. 47) is from 250 to 350 kg/m^3 and their coefficient of heat conductivity ranges between 0.015 and $0.085\text{ W/(m}^{\circ}\text{C)}$.

Ceramic and asbestos-containing heat-insulating products. Ceramic products intended to provide heat-insulation are prepared by molding, drying, and burning. Sedimentary rocks, such as tripoli, diatomite, are taken as raw materials.

To lower the density of ceramic products, use is made of foaming agents, combustible additions, and porous lightweight aggregates (expanded perlite and vermiculite).

Asbestos-containing heat-insulating materials contain 70-85% aggregates (diatomite, tripoli) along with the asbestos fibres. The main representatives of this group are asbestos-tripoli, asbestos-lime-diatomite, and asbestos-dolomite materials. Lightweight ceramic and asbestos-containing products are used for insulating industrial furnaces, boilers, and heating systems.

13.3. Organic Heat-Insulating Materials

Fibre, fibrolite, reed and peat boards are rigid organic materials, while felt and corrugated cardboard are flexible materials. Further we shall consider the materials often used by masons.

Fibre board is a sheet material obtained by molding and subsequent drying of wood-fibre mass with polymers added. Depending on their bending strength, fibre boards are assigned the following grades: soft, semisoft, rigid, and very rigid.

Soft boards (density 150-350 kg/m³, coefficient of heat conductivity 0.05-0.09 W/(m°C)) are used as an insulating material. They are usually 1 200-3 000 mm long, 1 200-1 700 mm wide, and 8-25 mm thick.

Fibrolite boards are manufactured from wood wool (fine long chips of wood) mixed with a mineral binder (portland cement). Depending on the density, fibrolite plates are manufactured in three grades: 300, 400, and 500. They are usually 2 000-2 400 mm long, 500-1 200 mm wide, and 30-100 mm thick. Their coefficient of heat conductivity is from 0.099 and 0.15 W/(m°C). They are utilized in making partitions and for thermal protection of walls and garret ceilings.

Reed boards, molded and woven with a galvanized wire, rectangular in shape, are manufactured from reed stems. Their density is about 250 kg/m³. Unfortunately, their application in the construction industry is restricted because they burn readily, decay, and are easily damaged by rodents.

Peat boards are manufactured from undecomposed peat by molding and subsequent drying. Their density is about

250 kg/m³. They are primarily used for thermal insulation of refrigerating chambers.

Corrugated board is prepared by pasting together smooth and corrugated paper sheets. It is usually available in 3 and 5 plies. Corrugator is used for making thermal insulated guards of prefabricated houses, and also for insulation of pipelines and equipment.

Plastic heat-insulating materials are usually grouped with organic materials. The types of raw materials used are polystyrene, polyvinylchloride (PVC), polyurethane and urea formaldehyde polymers, gas-forming and foaming agents, aggregates, plasticizers, and pigments.

Heat-insulating plastics, depending on their structure, can be cellular or foam, porous, and honeycomb.

Foamed and expanded plastics are obtained by foaming heat-softened polymers; the gases evolved upon thermal decomposition of the substances used expand the mass. The process is also assisted by the gases that evolve upon interaction of the components or upon evaporation of low-boiling liquids.

Honeycomb plastics are prepared by bonding paper sheets or fibre with thermosetting plastics in hot molds. The properties of heat-insulating plastics depend on their structure, properties of the polymer and the foaming agents used, and also on the density which varies between 10 and 250 kg/m³.

Heat-insulating plastics offer much resistance to water and are more durable compared to other organic heat-insulating materials. They find application for thermal insulation of exterior walls, roofs, and pipelines.

Chapter XIV

Plastic Construction Materials

14.1. Composition and Properties of Plastics

Plastics are materials made up of high-molecular organic resins—polymers or their combinations. They are called plastics because of their ability to become plastic at a certain stage of treatment to deform and take the required shape.

Composition of plastic masses. The main components of plastics are a binder, a polymer, fillers, plasticizers, curing agents, coloring agents, and stabilizers.

Polymers are high-molecular compounds, the molecules of which are made up of repeating units. Regenerated (synthetic) polymers used in the manufacture of construction materials are obtained from various raw materials, such as coal, crude oil, natural gas. The methods involve processing of raw materials at chemical plants followed by polymerization or polycondensation of the initial monomers.

During polymerization a large number of like molecules of simple compounds (monomers) combine to form a complex molecule (polymer) without separation of by-products. Polyethylene, polypropylene, polyisobutylene, and other synthetic polymers are obtained by polymerization.

Polymers of composition different from that of the initial products are obtained by polycondensation of several simple compounds; by-products like water and ammonia are formed in this case. Phenolformaldehyde, carbamide, polyamide, polyester, and other synthetic-base polymers are made by polycondensation.

Polymers can be thermoplastic or thermosetting, depending on their behaviour on heating or cooling.

Thermoplastic polymers become elastic on heating or rigid after cooling. They have the property of large electrical resistivity, low moisture absorption, and high resistance to chemicals. They also exhibit low heat stability, low hardness, readily swell and dissolve in organic solvents. Most of the polymerized polymers fall into this group.

Thermosetting polymers harden under the action of heat and pressure; they do not become elastic on reheating. They differ from thermoplastic polymers in high strength, heat stability, and hardness. With them are grouped formaldehyde, carbamide, epoxide, and certain other types of polymers.

Fillers. Powder (ground quartz, chalk, talcum, wood flour, etc.), fibrous (asbestos, wood, glass fibres), and laminated fillers (paper, cotton fabric, glass fabric, wood veneers, etc.) are used for making plastics. Fillers impart the property of high strength, heat stability, acid resistance, durability, increased toughness to polymers. Besides, they cost much less than polymers; their use in plastic masses considerably lowers the cost of plastics and plastic goods.

Plasticizers are employed to improve the molding properties of plastics. Dibutyl phthalate, camphor, oleic acid are used as plasticizers.

Curing agents and stabilizers are added to reduce the curing time of plastics, to accelerate the manufacturing process and for raising their life expectancy period.

Coloring agents are used to give different colors to plastics. Organic (nigrosine, chrysoidine) and mineral (ochre, red lead, red ochre, umber, etc.) pigments which remain stable with time and to the action of sunlight are employed as coloring agents.

Plastics possess a number of important physico-mechanical properties that offer an advantage over other widely available construction materials. They are: the wide range of density (the density of porous plastics varies between 15 and 50 kg/m³ and of compact plastics from 1 800 to 2 200 kg/m³), high strength (the compressive and bending strength of compact plastics is, respectively, 70-100 MPa and 40-50 MPa), low heat conduction (especially in foamed and porous plastics), high resistance to chemicals, resistance to corrosion, high wear-resistance, ductility (this property enables plastics to be easily extruded, cast into forms or molded), easy machining (plastics can be cut, bonded (glued) with each other or other materials), possibility of making thin-film plastics, and highly hygienic properties (dirt particles and soilings are readily removed from plastics). The following are the disadvantages of plastics: low heat stability (at temperatures exceeding 200°C plastics lose their properties), creep (ability to plastic flow even at room temperatures), high coefficient of linear expansion, ageing (the color becomes dull), and spontaneous brittle rupture.

Despite these adverse properties, plastics are used by a variety of trades. Different methods can be used to make plastic products in final finished form. Among them are injection molding (polystyrene tiles), extrusion molding (pipes, handrails, plinths, etc.), pressure molding (rolls, for example, linoleum), form molding (door handles, door knobs, pulls, glides, etc.), and hot molding (paper-laminated stripping).

14.2. Plastic Construction Materials

Plastics have made an astounding infusion into the construction industry. There is almost no trade or segment of

the construction industry that does not use plastic in one form or another. Plastics are used as floor covering in domestic, administrative, and industrial buildings, as finishing and structural materials. In the plumbing and heating/air conditioning trades, pipes, couplings, elbows, union tees, shower stalls and tubs, sewer system parts, joints and tapes are made from various plastics.

Materials used for floor covering can be divided into rolls (linoleums, synthetic carpeting materials), tiles, and mixes, the latter being used for making jointless floors.

Linoleums and carpeting. Polyvinyl chloride (PVC), alkyd, rubber, and other synthetic linoleum and carpeting are available in rolls; they can be without a base or coated with a heat- or sound-absorbing material. The face surface of linoleums and carpeting can be smooth, fluted or fleecy. They can be of one color or multi-colored.

PVC linoleums are manufactured without a base or with a fibre base, heat- and sound-absorbing felt or porous base. One-ply linoleum is usually 1.5-2.5 mm thick; felt- or porous-base linoleums are 4-6 mm thick. Linoleums are used for covering floors in domestic, civic, and industrial buildings.

Glyptal (alkyd) linoleum 2.5-3.0 mm thick is manufactured with fibre backing. Such linoleums are used as floor covering in office buildings.

Rubber linoleum is made of two-ply rolled type, the underlayer of which is made up of vulcanized mixture of old ground tires, bitumen and cord fibre; the upper layer 4-6 mm thick is built up of colored and synthetic rubber with heat- and sound-absorbing porous backing. Such linoleums are widely used as floor covering in corridors of public and industrial buildings.

Carpeting made from synthetic fibres is manufactured with a 5 mm thick spongy latex backing or with a PVC base. The upper layer of carpeting has a nap of polyamide nylon fibre or of polypropylene yarn. Synthetic carpetings are noted for their good acoustical and heat-insulating properties, abrasion resistance, minimal fire hazard (they melt); they can be glued to form a room-size carpeting and cleaned up with liquids. Used as floor covering in theatres, concert halls, hotels, and auditoriums.

Floor tiles are manufactured using synthetic polymers (polyvinyl chloride, indene coumaric polymer or rubber). They are available in the following sizes: 200 × 200 mm,

300 × 300 mm, and 500 × 500 mm, their thickness varies from 1.5 mm to 7.5 mm. Such tiles are employed in buildings where the use of linoleum with polymer backing is recommended (Fig. 48).

Different mosaics can be formed using floor tiles. Besides, the tiles can be easily glued or replaced; the amount of polymers used in the manufacture of tiles is less than required for analogous roll materials; there is almost no wastage in making floors with such tiles. Tile floors are durable, resistant to chemicals, and have a high abrasion resistance. Unfortunately, large number of seams make such floors less hygienic and more labour-consuming compared to linoleum floors.

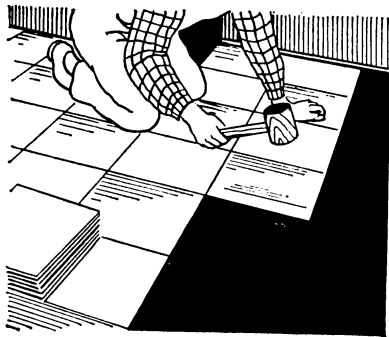


Fig. 48. Pasting tiles on cold mastic

Materials for jointless floors are selected with due consideration of the type and the utility of the floor. Floors are made by applying one or several coats of mixes containing synthetic binders, powder-like aggregates, and mineral pigments.

Mixes, according to their consistency, can be mastics, mortars, and concretes. Polyvinyl acetates, polyesters, epoxides, and polymer cements are used as initial binders.

Mastic floors using synthetic binders are seamless coverings 3-5 mm thick. They are given different colors by adding pigments like ochre, red lead, ultramarine blue, etc.

Polymer-cement mortar floors are made from a mixture of portland cement and polyvinyl acetate emulsion with aggregates like sand, marble chips, and mineral dyes. They are usually 7-10 mm thick.

Polymer-cement concrete floors are made from synthetic binders and aggregates mixed with coarse (6-10 mm) mineral fillers (basalt, garnet). Such floors are usually about 20 mm thick.

Continuous floors are strong, wear-resistant, resilient, hygienic, have good appearance, and are simple to attend to. Such floors are installed in industrial buildings.

Finishing materials. Interior finishing materials are produced in rolls, sheets, and tiles.

Polyvinyl chloride films, lincrusta (a heavy type of wallpaper), and wallpapers are usually produced in finished-width rolls.

Polyvinyl chloride films are produced without a backing or with paper, fibre, or sound-absorbing elastic backing. They may be transparent, semi-transparent, opaque, colored, without or with printed on patterns, smooth or embossed. Such films are marketed as leaves 12-30 m long, 500-1 800 mm wide, and 0.15-0.8 mm thick. They exhibit sufficient rupture strength, are hygienic, elastic, offer resistance to vapour-, water-, and gas-penetration, are resistant to the action of acids, alkalies, and oils. Used for finishing interior walls, partitions, ceilings, and door leaves in places where sanitation is important.

Lincrusta is produced with embossed surface, and may be colored or uncolored. It is made with paper backing. Lincrusta is usually available in 12 m long finished-width rolls 500, 600, and 750 mm wide. It is not subject to decay. Used for finishing walls, partitions, built-in furniture in public buildings.

Washable wallpapers are produced by applying a thin coat of synthetic resin or by pasting transparent PVC film on usual wall-papers. Usually they have embossed surface imitating a fibre or other materials. Cloth and vinyl wall-papers are much more durable, retain colors longer, are washable, and in many cases can be removed and reinstalled. Public restroom walls, hospitals, and school corridors are frequently finished with these types of wallpapers.

Laminated finishing materials are subdivided into wood-particle boards, woodfibre boards, and paper-backed plastic sheets.

Woodparticle boards are made by combining wood particles with polymers and hot pressing them into the panels, the face surface of which is covered with plastics, veneer, lacquer, enamel or paints. Particle boards are produced in thickness ranging from 10 to 22 mm. As sheets they are usually 1 250-1 750 mm wide and 2 500-3 500 mm long. Particle boards are used for making partitions, false ceilings, furniture, etc.

Woodfibre boards are manufactured by hot pressing wood fibres impregnated with synthetic polymers. Common sizes of fibreboards are: thickness 3-6 mm, width 1 200-1 800 mm,

length 1 200-3 600 mm. Fibreboard panelling is used extensively in both commercial and residential interiors.

Papers-backed plastics for decoration purposes are produced by hot pressing of several layers of polymer-impregnated paper, and are made in numerous colors and with wood-grain patterns. They are usually produced as sheets 600-1 600 mm wide, 1 000-3 000 mm long, and 1-5 mm thick. The density is 1 400-1 500 kg/m³ and the bending strength is about 100 MPa. Paper-backed plastics do not melt, are frost-resistant, easily cut, and can be drilled. Used mainly in commercial interiors.

Structural polymers include glass-reinforced plastics and wood-laminated plastics.

Glass-reinforced plastics are made of a binder (polymer) and an aggregate (glass fibre). It is marketed as thin fibrous sheets and also in the form of fittings, units, and assemblies. Depending on the kind of aggregate used, glass-reinforced plastics fall into the following categories: sheets with chopped glass-fibre aggregates, glass-cloth-base constructional laminate, glass-reinforced plastic sheets with continuously orientated glass-fibre base.

Glass-reinforced plastics have a high strength, water resistance, corrosion and chemical resistance. Load-bearing structures, fencing walls, and roofs are made from such plastics.

Wood-laminated plastics are thin sheets obtained by hot pressing of polymer impregnated wood-veneer stacks. As sheets they are usually 700-5 600 mm long, 800-1 200 mm wide, and range in thickness from 1 to 2.5 mm.

Wood-laminated plastic sheets feature high strength, have a charming golden-grey surface with wood grain patterns. They are easily cut, drilled, nailed and fastened with screws. Used for finishing walls, partitions, and in ceiling boarding of public buildings.

Continuous polymer constructional goods are lengthy products of varied profiles, colour, and utility. Among them are plinths, handrails, stair treads, door/window casings, window insulating stripping, etc. These are used in place of wooden goods, for they exhibit high elasticity, heat stability, chemical resistance, impermeability, and have sanitation properties.

Plastic pipes are manufactured from polyethylene or polyvinyl chloride by the extruded method; the diameter of pipes ranges between 6 and 150 mm and the wall thickness varies from 2 to 8 mm. Such pipes find application in lay-

ing water-supply lines, sewer nets, ventilation systems, and in the electrical trade. Resistance to corrosion, chemical resistance, and lightness are their main advantages. Plastic pipes can be easily welded.

A large variety of types, shapes and kinds of construction products are made of plastics or of plastic in combination with metals. Among them are wash basins, sinks, water-closet pans, tubs, flush tanks, siphon traps, mixers, registers, etc. These plastic products are lightweight, have sufficient strength, are not prone to corrosion, hygienic, and have pleasing look.

Plastics have added a new dimension to the construction industry. Since so many products are in the final finished form, the use of plastic products lowers the labour input and the construction cost, improves the quality of the construction job, and reduces the consumption of ferrous and non-ferrous metals, wood, and other critical materials by the construction industry.

Mastics and glues are paste-like or liquid bonding materials consisting of polymer binder, solvents, plasticizers, aggregates, thinners, and, in some cases, hardeners. Depending on the kind of binder (gluing base) used, mastics and glues are divided into various categories as follows: bitumen, resin, rubber, colloxylin (nitrocellulose), and casein. According to the method of application, mastics can be hot, not very hot, and cold.

Hot bitumen, cold bitumen, bitumen-vulcanized rubber, bitumen-natural rubber, colophony, coumarone-natural rubber, phenol formaldehyde, colloxylin, diphenyl, casein-cement and other mastics are used for pasting various kinds of roof materials, polymer tiles and sheets in floor covering, and also to bond lengthy articles.

Urea and urea-formaldehyde glues, phenol-resorcinol glues, polyisobutylene resins, colophony, coumarone, diphenyl, and casein-cement mastics are used in finishing walls, ceilings, and built-in furniture with different kinds of rolls, tiles, and sheet materials.

For gluing structural elements use is made of phenol, epoxide, polyester, urea, and natural rubber glues.

The following requirements are placed upon glues: high adhesion to materials to be glued, and the strength of the bonding must not be less than that of the materials being bonded, sufficient longevity, desired viscosity, fast curing, and low cost.

Necessary sanitation and fire protection measures must be taken in storage, transportation, and applying glues and mastics.

Chapter XV

Paints and Varnishes

Paints and varnishes are ready mixes that are applied in the liquid state to the surface of construction products or structural elements and form hard coating films after drying. The films formed firmly adhere to the surface being painted, exhibit sufficient strength and longevity, protect the base material against the action of aggressive agents, impart decorative look to the painted surface, and improve the hygienic conditions. Paints, varnishes, and other auxiliary materials are composed of various ingredients including binders (vehicles), pigments, fillers, solvents, and sometimes dryers.

15.1. Basic Components of Paints and Varnishes

Vehicles or binders are the main constituents of paint formulas. Paint vehicles are materials that hold the pigment together and also adhere to the surface, which according to the composition are subgrouped into three categories: those that are used for oil paints, for water paints, and emulsions.

Vegetable and mineral oils, synthetic resins are the most common binders for oil paints. Enamel paints are prepared using oil varnishes as binders.

Drying oils are made from vegetable and mineral oils; they can be natural, mixed, and synthetic.

Natural drying oils are obtained by boiling vegetable oils (linseed, hempseed) with siccatives (paint dryers)—oxidizers which accelerate the drying process. The films that are formed upon drying (hardening) are highly weather resistant and ductile.

Mixed drying oils are prepared by diluting the thickened vegetable oils with organic solvents. They are cheaper than natural drying oils. The films formed after drying are thinner and more glossy, but less durable.

Synthetic drying oils are obtained from petroleum products by adding to them about 35% (by mass) vegetable oil or without the addition of vegetable oil. In the former case, glyptal drying oil is obtained; shale and synthole drying oils are recovered in the latter case.

Oil varnishes are natural or synthetic resins dissolved in vegetable oils with siccatives and solvents.

Vehicles for water paints are prepared from mineral binders and different kinds of glues. In water paints, white portland cement and lime act as white pigment and binder. Potassium water glass is used as binder in silicate paints.

Animal, vegetable (protein), and synthetic resin glues can also be used as binders in water paints. Animal glues include casein, bone, and gelatin glues. Vegetable glues are obtained by mixing starch, wheat flour or dextrin (starch gum) with hot water until a creamy paste is formed.

Synthetic resin glues are solutions of synthetic polymers in water.

Emulsions used as binders in paints are prepared in emulsifiers using drying oils, lime milk, and animal glue. Their application makes it possible to save critical drying oils.

Pigments are colour powders obtained upon grinding natural and synthetic minerals and organic compounds. They do not dissolve, but remain suspended in water or organic solvents (oil, spirit, turpentine) thereby forming paints. Mineral pigments that exhibit high resistance to chemicals and are light- and weather-resistant are used extensively in the construction industry.

Natural mineral pigments are obtained by grinding rocks. Chalk, ochre, iron minium, graphite, mummy, and umber are the most abundently available natural pigments.

Synthetic mineral pigments are obtained by chemical processing of mineral raw material followed by grinding.

Among the synthetic white pigments, wide use is made of lead, zinc, lithopone, and titanium white paints. Colour pigments give the coating material its colour. This may be an inorganic type such as chrome yellow, red lead, mummy, cinnabar, ultramarine, azure, chromic oxide, zinc green, lead green, carbon black, and manganese dioxide. Synthetic pigments consist of metal powders (aluminium and bronze powders).

Synthetic organic pigments are obtained from aniline, naphthalene, and various hydrocarbons as organic dyes

which when precipitated on a white extender change into pigments.

The following physical characteristics determine the quality of pigments: coverage or spreading rate is the amount of pigment used (in grams) for 1 m² area; dyeing power is the ability of a pigment to give its colour to the mix with white pigment; fastness to light or light resistance is the ability to retain colour under sunlight; weather resistance, that is, pigments do not fade under the combined action of temperature, sunlight, moisture, carbonic acids; resistance to corrosion and fire.

Fillers are insoluble materials; most of them are white in colour and are added to paints for saving of pigments and imparting them special properties, for instance, increased strength, resistance to acids and fire. In making paints, kaolin (China clay), ground talcum, dust-like quartz, asbestos dust, mica, and other milled materials are used as fillers.

15.2. Finishing Materials (Paints)

Finishing materials (paints) that are widely used by the construction industry can be oil paints, varnishes, and enamels, water-lime, water-glue, and volatile resin paints.

Oil paints are prepared in colour mills by rubbing up pigments, fillers, and binders until a creamy paste is formed, and are marketed as pigment pastes and ready-mix paints. Drying oil or emulsion diluents are added to adjust the consistency of pigment paints so that they may be readily applied to the surface. Oil paints are applied on metal, wooden, and plastered surfaces.

Oleoresinous, synthetic, bituminous, spirit, and nitrocellulose varnishes are used as finishing materials.

Oleoresinous varnishes are employed as binders in making paints. They can also be used to give top coating on oil paints and for surface coating of wood and metal products.

Synthetic varnishes are prepared from urea formaldehyde polymers and used to coat parquet floors and woodwork.

Bituminous or asphalt varnishes are prepared by dissolving bitumen and applied as anticorrosive coating to steel pipes.

Nitrocellulose varnishes are produced by adding plasticizers to the nitrocellulose dissolved in organic solvents. They dry fast and produce a glossy surface. Used to coat wooden articles.

Spirit varnishes and French polish are natural or synthetic polymers dissolved in spirit. French polish, unlike varnish, contains very small amounts of dissolved polymer.

They are used to polish wooden surfaces and are applied as coating to metals and glass.

Enamels are produced by rubbing up dry pigments with glyptal, pentophthalic or perchlorvinyl varnishes. The ability to form a film of increased hardness determines the field of application, that is, enamels are used to paint metallic and plumbing products and floors.

Water-lime paints are prepared by mixing common lime or hydraulic lime which is suspended in water, and mineral pigments (ochre, azure, green, etc.). They are used to paint walls, ceilings, and faces of buildings.

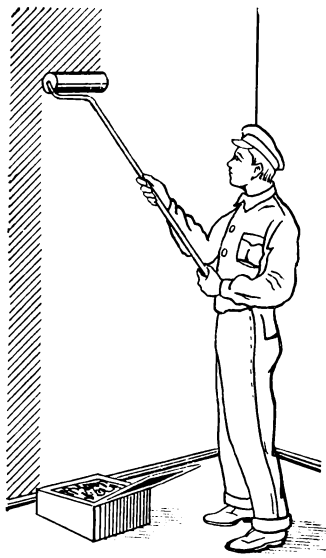


Fig. 49. Applying polyvinyl acetate paint on walls by roller

Silicate paints are dry mixes of mineral pigments and ground chalk, which are mixed with potassium water glass prior to their application. Used for painting faces of buildings.

Distemper or tints are a mixture of pigments and milled chalk. Before using they are mixed with water solution of animal glue or vegetable adhesives. They are applied on both interior and exterior surfaces.

Latex emulsion paints are made with synthetic materials that are dispersed in water. The most common are polyvinyl acetate, styrenebutadiene, and polyvinyl chloride emulsions. They are applied by rolling or spraying (Fig. 49) to the prepared surface. Latex emulsions dry fast and form water- and weather-resistant coatings.

15.3. Auxiliary Materials and Wallpapers

Auxiliary materials, such as solvents, thinners, siccatives, underlying hard fillers, primers, putty are used in plaster and point work.

Solvents are liquids used to adjust the consistency of paints so that they may be applied readily to the surface. They are classified according to their utility into those for oil paints (spirit, white spirit, turpentine); for glyptal and bitumen paints (solvent-naphtha, turpentine); for perchlorvinyl paints (acetone, etc.); for distempers and water-emulsion paints (water).

Thinners are employed to reduce the viscosity of paste paints or for diluting dry mineral paints. Thinners, unlike solvents, contain film-forming materials in amounts necessary for a quality paint coating to be formed. Drying oils and various emulsions are used as thinners.

Siccatives are solutions of metal fatty acids in organic solvents. They are added in small amounts (5-8%) to drying oils and oil paints for fast drying of the films.

Fillers, depending on the kind of paint to be used, are employed to fill low spots on the surface to be painted.

Primers ensure bonding of the coating with the surface being painted. Oil paint thinned with drying oil or diluent is used as prime coat for oil paints; vitriolic primer containing household (laundry) soap, glue solution, drying oil, copper sulfate, and chalk is used for distempers.

Putties are pastes employed for spreading window cross casements when glazing, rabbet and other types of joints in sheet roofing. Usually they are mixtures of natural drying oil, chalk, minium or white paint. Putties exhibit excellent water resistance and plasticity.

Wallpapers (unprimed, primed, embossed, metal-coated, etc.) are now widely used for interior walls. Wallpapers are made exclusively from paper or combined with other



Fig. 50. Hanging of wallpapers

materials; one colour or multi-colour patterns are printed on the face surface. Usual and washable wallpapers are produced in finished-width rolls (see Chapter XIV).

Usual wallpapers are available in different colours.

Unprimed wallpapers have patterns directly painted on to the white or coloured paper (background). Distemper is used for making patterns on wallpapers.

Primed wallpapers are made from paper coated with a colour-primer to which one-colour or multi-coloured patterns are then printed on.

Embossed wallpapers are usually made from primed wallpapers to which patterns are printed on using oil paints with simultaneous embossing.

Metal-coated wallpapers are prepared from wallpaper to which a primer with a metallic powder is coated and then the patterns are printed on or embossed.

The surfaces to which wallpapers are to be hanged are dried, levelled, and freed from chalk or lime solution; all the cracks, slits, and pits are filled up with lime-gypsum solution. Wrapping paper or newspapers are pasted on to the prepared surface and then the wallpaper is hanged (Fig. 50).

Pastes prepared from wheat flour, starch, joiner's glue, synthetic resin adhesives, and gluing mastics are used to paste papers on walls and for hanging wallpaper.

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